EFFECTIVENESS OF DIGITAL GAME-BASED LEARNING IN ENHANCING PRIMARY FOUR PUPILS' ACHIEVEMENT IN FRACTION

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ABSTRACT

Fraction is one of the basic concepts in Mathematics but the general understanding of the concept is still inadequate among pupils in elementary schools. A hindrance in the method of teaching and the lack of technological tools in the topic of fraction have led to the need of a deeper understanding about the causes of low achievement among Malaysian pupils in Mathematics. This study aims to examine the effectiveness of a digital game-based learning in enhancing Primary Year Four Pupils' achievement in fraction. A quasi-experimental research design was conducted to answer the three research questions of this study. The sample of this study consists of 56 pupils Year Four primary pupils from two equal sizes of intact classes in one of the Chinese primary schools (SJKC) in Kuala Lumpur. They participated in this study with one class assigned as the control group (N= 28) and the other as an experimental group (N = 28). The experimental group was taught using the Zapzapmath app as digital game-based learning which is designed based on cognitive information processing theory and Gagne's conditional theory. The intervention for the experimental group was conducted for six weeks. The control group was taught using the traditional approach. Pre and Post Fraction Achievement Test were administered to pupils in both the experimental group and the control groups before and after the intervention. Inferential statistics such as Wilcoxon signed-rank test and Mann-Whitney U test were used in analyzing the quantitative data obtained. Results of Wilcoxon signed-rank test indicated that there were no significant difference between the means of the pre-test and post-test of the pupils in control group, when $z = -1.04$, $p = 0.30$. After six weeks of intervention, the results of the Wilcoxon signed-rank test had shown that there was a significant difference between the means of the pre-test and post-test of the pupils in experimental group ($z = -4.56$, $p < .001$). This means that pupils in the experimental

group have improved significantly in post-test as compared to the pre-test after the digital game-based learning approach. Furthermore, results of the Mann-Whitney U test revealed that the post-test for the experimental group and control group were statistically significantly different, $U\,(n_1 = 28, n_1 = 28) = 52.50$, $z = -5.56$, $p < .001$). This means that the pupils in the experimental group achieved significantly higher scores than the pupils in the control group for the post Fraction Achievement Test.

In short, this study concludes that the use of digital game-based learning apps in teaching fraction is more effective than the traditional teaching approach; and it has helped the pupils to learn fraction more effectively.

Keberkesanan Pembelajaran Berasaskan Permainan Digital Untuk Peningkatan Pencapaian dalam Pecahan Murid Sekolah Rendah Tahun Empat

ABSTRAK

Pecahan merupakan salah satu konsep asas dalam mata pelajaran Matematik tetapi pemahaman konsepnya masih kurang difahami murid-murid di sekolah rendah. Halangan dalam cara pengajaran pecahan dan kekurangan penggunaan alat teknologi merupakan faktor yang menyebabkan pencapaian yang rendah di kalangan murid-murid di Malaysia dalam mata pelajaran Matematik. Kajian ini bertujuan untuk mengkaji keberkesanan pembelajaran berasaskan permainan digital untuk meningkatkan pencapaian pecahan dalam kalangan murid sekolah rendah Tahun Empat. Reka bentuk kajian kuasi-eksperimen telah dijalankan untuk menjawab tiga soalan kajian ini. Sampel dalam kajian ini melibatkan lima puluh enam orang murid Tahun Empat dari dua kelas utuh saiz yang sama di salah sebuah sekolah jenis kebangsaan Cina (SJKC) di Kuala Lumpur. Mereka yang terlibat dalam dua kelas telah mengambil bahagian dalam kajian ini telah ditugaskan sebagai kumpulan kawalan (N= 28) dan yang lain sebagai kumpulan eksperimen (N= 28). Kumpulan eksperimen telah menjalani rawatan dengan menggunakan perisian *Zapzapmath* yang berlandaskan kepada teori pembelajaran cognitif dan teori pembelajaran Gagne. Rawatan bagi kumpulan eksperimen telah dijalankan selama enam sesi pembelajaran. Kumpulan kawalan diajar dengan menggunakan pendekatan tradisional. Ujian pra dan ujian pasca *Fraction Achievement Test* ditadbirkan kepada murid-murid dalam kumpulan eksperimen dan kumpulan kawalan sebelum dan selepas proses intervensi. Statistik inferensi seperti ujian *Wilcoxon signed-rank* dan ujian *Mann-Whitney U* diaplikasikan untuk menganalisis data kuantitatif yang diperoleh daripada kajian. Dapatan ujian

Wilcoxon signed-rank menunjukkan bahawa tiada perbezaan yang signifikan antara purata ujian pra dan pasca dalam kumpulan kawalan apabila z = -1.04, p = 0.30. Selepas proses intervensi selama enam minggu, keputusan ujian *Wilcoxon signed-rank* menunjukkan bahawa terdapat perbezaan signifikan antara purata ujian pra dan pasca dalam kumpulan eksperimen (z = -4.56, p ‹ .001). Ini bermakna murid dalam kumpulan eksperimen telah meningkat secara signifikan dalam ujian pasca apabila berbanding dengan ujian para selepas pembelajaran berasaskan permainan digital. Di samping itu, ujian *Mann-Whitney U* menunjukkan bahawa terdapat perbezaan signifikan secara statistik, U $(n_1 = 28, n_1 = 28)$ = 52.50, z = -5.56, p ‹ .001 antara kumpulan eksperimen dan kumpupan kawalan dalam ujian pasca. Ini bermaksud murid dalam kumpulan eskperimen memperoleh skor yang lebih tinggi secara signifikan berbanding dengan murid dalam kumpulan kawalan selepas intervensi.

Secara ringkas, kajian ini dapat disimpulkan bahawa penggunaan aplikasi permainan digital dalam pembelajaran pecahan adalah lebih berkesan daripada pendekatan tradisional dan ia telah membantu murid-murid dalam mempelajari topik pecahan dengan lebih berkesan.

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CONTENTS

Chapter 3: Methodology

Chapter 4 : Findings

Chapter 5: Discussion and Conclusion

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Learning mathematical concepts and knowledge especially in the area of Fraction plays an important role in succeeding in upper level mathematics courses (Siegler et al, 2012). Fraction is one of the major topics in mathematics that need to be mastered (Tian & Siegler, 2016; Mousley & Kelly, 2018) and it becomes an important indicator of prospective pupils' in various career options (Tang, Voon & Nor, 2010) such as nursing, carpentry and auto mechanics. According to the National Mathematicsc Advisory Panel (NMAP, 2008) and other researchers (Bailey, Hoard, Nugent & Geary, 2012; Booth & Newton, 2012; Shellenbarger, 2013; Siegler et al., 2012), the knowledge of fraction is a strong predictor for future mathematics achievements; in other words, pupils who failed to gain proficiency in Fraction during primary school or early secondary school, tend to struggle in later grades as Fraction become more embedded in advanced mathematics domains that includes algebra.

Therefore, understanding Fraction is an essential knowledge to master if pupils wants to progress in advanced level mathematics such as algebra or calculus (Bailey, Siegler & Geary, 2014). The main components of teaching Fraction include the properties of magnitude, order, equivalence, comparisons and operations of fraction, finding the relations between them, describing, explaining and proving the relationship between whole numbers and Fraction (Mousley & Kelly, 2018). It is important to teach the concept of fraction well because it is closely related to other topics such as decimals, percentages, algebra, probabilities, functions and calculus (Idris, 2011). It is also one of the more prominent ways for pupils to master basic knowledge in Fraction such as comparisons, analyzing patterns, making generalizations in order to achieve better scores in the concept of Fraction that are commonly used in our daily lives (Rejeki, Setyaningsih & Toyib, 2017).

Fraction is a topic that is suitable to be taught by integrating technology during lessons (Thambi & Leong, 2013). This is because Fraction require pupils to see how any changes in denominators and numerator could affect each other. By integrating technology, it can help pupils to visualize what they have seen and also understand the Fraction concept better as compared to performing a sequence of algorithm operation to get the final answer. According to the National Council of Teachers of Mathematics (2000), technology is included in one of the six principles of teaching mathematics in school, as it mentioned that technology is essential in the teaching and learning mathematics; it influences the way mathematics is taught and enhances pupils' learning (p.24). In the study of Ahmad and Latih (2010), they suggested that the use of new digital game-based application can help to enhance pupils' thinking skills of fraction and providing pupils an alternative to improve their learning performance using games. Lowrie and Jorgensen (2015) also emphasized the importance of developing pupils' knowledge of Fraction and high-order thinking skills in the teaching and learning of Fraction with digital games. This is important since the knowledge of Fraction is crucial in many areas of studies such as technology, science, medicine, occupation as well as in mathematics.

In this study, the researcher has uncovered several critical issues related to the study of Fraction. Firstly, the teaching of Fraction in school hardly improve pupils' scores in Fraction due to the lack of understanding in solving "applying" and “reasoning” questions (Ministry of Education, 2013). The pupils were taught by rote or traditional teacher-centered learning approach (Aslan, 2011) in the process of teaching and learning Fraction since primary level. For example, pupils were taught to memorize the rules of fraction algorithms to solve the problem instead of understanding the meaning behind fraction (Misquitta, 2011). Some studies showed that teachers tried to use various methods to teach Fraction by relating the questions to real world problems such as using manipulative materials, building area model, and real-world applications. However, the main strategies of teaching remain to be direct teaching methodology or the traditional teaching method which do not encourage pupils to think laterally or work collaboratively, which might help them understand the concept better (Aslan, 2011). At the end of the study, the methods teachers used to teach Fraction had turned out to be incorrect. Rejeki, Setyaningsih and Toyib (2017) suggested that teachers should guide pupils to focus on ways of reasoning and computation of Fraction instead of memorizing the rules and definitions, which only the bright pupils could master. However, most of the pupils commonly follow step-by-step instructions in traditional learning methods through lectures and listening to the steps of operation explained by teachers in classes without understand the real concept of Fraction on their own (Isiksal & Cakiroglu, 2011; Khairunnisak, Maghfirotun, Juniati & de Haan, 2012, Simsek, 2016). Therefore, pupils faced difficulties in mastering Fraction and obtains lower achievement in assessments as they do not have sufficient conceptual knowledge of Fraction (Thambi & Leong, 2013).

Besides that, Malaysian secondary pupils did not perform well in the international assessment regarding Fraction (Hassan, Rosli & Zakaria, 2016). Although the international assessment is designed for secondary school pupils, their basic concepts and knowledge on Fraction must be developed from the primary school level. They are two types of international assessments such as the Programme for International Pupil Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) where Malaysia's rank was not at satisfactory level. The PISA assessment is similar to the TIMSS assessment, in which both are aimed to test pupils' knowledge and skills in the field of Mathematics. According to Hassan, Rosli and Zakaria (2016), studies indicated that almost 60% of students aged 15 years who joined PISA failed to reach the minimum level of skills in mathematics which includes the topic of Fraction. Their studies also found out that in terms of mathematical achievement, Malaysia was ranked 57th by attaining 404 points; below the average of 458 points at the OECD level (Organization of Economic Operation and Development). As a result, our pupils' performance in mathematics is still very weak and performed very poorly in mathematical assessments (Effandi, Lu & Md. Yusoff, 2010).

The report of TIMSS (1999-2011) had clearly shown that the average mathematics scores obtained by Malaysian pupils for TIMSS in 1999 was 519, plummeted to 440 for TIMSS in 2011 (Mullis, Martin, Foy & Arora, 2012). According to the report, only 32% Malaysian pupils were able to solve problems using operations with fraction. This percentage shows the number of students who answered the fraction and decimals section correctly in TIMSS. This result also indicated that about lesser than half of the pupils in 8th grade lack of knowledge and skills related to Fraction even when the topic of fraction and decimals consist of only 15% in the entire TIMSS assessment.

According to Mullis et al., (2012), the curriculum in TIMSS contains both content domains and cognitive domains. The content domains covered in TIMSS 2015 are Numbers (30%), Algebra (30%), Geometry (20%) and Data and Chance (20%) whereas the cognitive domains includes knowing procedures (35%), applying skills (40%) and reasoning skills (25%). In TIMSS 2015, Malaysia scored 465 in mathematics showing a significant improvement of 25 points from TIMSS 2011, when it was at 440 points, which was the lowest score in 2011. Even though the performance of Malaysia pupils had been slightly improved in TIMSS 2015, the result was not at a satisfactory level in Malaysia. According to the report of TIMSS 2015, our former Education Ministry director Tan Sri Dr Khairi Mohamad Yusof mentioned that Malaysia has aimed to achieve an international average score of 500 points in both subjects for mathematics and science by TIMSS 2019. Therefore, in order to achieve the target in TIMSS 2019, there is a strong need to help pupils to enhance their achievement in Fraction.

Lack of using digital game-based application in enhancing fraction achievement has also become a concern in this research. In recent years, teaching and learning with digital technology has become one of the most important goals of education. According to the Malaysia Education Blueprint (2013-2025) report, the use of digital technology such as computers or mobile devices in teaching and learning are seen as essential learning tools to transform our educational process in order to support the development of higher order thinking skills (p. 6-20). However, local research has found out that even though Malaysia pupils were familiar with advanced technology like computers, the implementation of digital game-based application as a teaching practice in classrooms has yet to be carried out (Osman & Bakar, 2012). The researchers further explained that it is due to the implementation of digital game-based application in mathematics especially in Fraction is still relatively new and for some, still foreign among teachers and pupils. Besides that, there is also a lack of expertise in administering the technology among primary teachers in Malaysia.

In fact, digital game-based applications were widely used in education in many countries known as "educational games" were used in teaching and learning mathematics to help pupils improve mathematical knowledge and skills effectively from game instruction, which provides them with useful feedback, desirable goals and opportunities (Zin, Jaafar & Yue, 2009; Kickmeier-Rust, Michael, Mattheiss, Steiner & Albert, 2011). Recently, there has been a movement in the trends of games for learning mathematics which mainly focuses on the use of digital game-based applications as mentioned in the study of Rejeki, Setyaningsih and Toyib (2017). In this study, one of the educational games used in the teaching and learning of mathematics is named Zapzapmath application. Moreover, this study aims at investigating the effectiveness of using Zapzapmath application as a digital game-based learning application in order to enhance Year Four pupils' achievement in Fraction.

1.2 Problem Statement

The first issue is related to the teaching practices among mathematics teachers is the use of traditional teacher-centered approach in the teaching of Fraction in classrooms. According to Pili and Aksu (2013), the traditional teacher-centered approach is defined as the use of traditional instructions, methods and standard tools of mathematics such as rulers, pencils, and paper to teach the contents of mathematics in classrooms. They further stressed that in the case of using traditional methods in teaching mathematics, teachers usually provide a set of instructions using abstracts examples and words to explain the mathematical concepts. A research in Malaysia revealed that the pupils spent the highest amount of learning hours in listening to the instructions and explanation by teachers and then solve the mathematical problems with guidance (Idris, 2011). This method of teaching can put a lot of pressure on pupils and lower their capacity for achieving better grades in mathematics.

There are several research studies which reported that with the use of traditional teaching approaches, majority of the pupils were taught how to use algorithms in solving Fraction with whole numbers without emphasizing on the meaning behind it (Khairunnisak, Maghfirotun, Juniati & de Haan, 2012). Moreover, even when the pupils learn to perform these fraction operations using only rules, soon they forget the rules, which results in the inability to solve the problems of Fraction and thus they find it difficult to solve such problems with said operations (Isiksal & Cakiroglu, 2011). Similar to the study of Dogan and Icel (2011), failures and low achievement in mathematics were due to the use of traditional teacher-centered approaches that forced pupils to learn mathematics through rote memorization to solve mathematical problems. As pupils learned Fraction through rote memorization of procedures without connection "between what is taught and their informal ways and means of operating", they faced serious difficulties in mastering the basic concept of Fraction (Steffe & Olive, 2001). Dogan and Icel (2011) further explained that the process of learning mathematics with specific skills requires the ability of applying, reasoning, critical thinking and imagination in order to relate to the actual knowledge, where the technological tools are playing a vital role to achieve this.

In fact, a study in Malaysia was conducted by Hussain, Hoe and Idris (2017) which suggested the use of technology, such as a digital game-based learning is a form of student-centered learning which utilizes digital game applications with the purpose to improve the academic performance of pupils, especially in the area of fundamental mathematical knowledge and skills. Based on the Malaysia Education Blueprint (2013-2025) report, Malaysian mathematics teachers are encouraged to deliver, support and enhance the teaching and learning in classrooms using digital technology, which potentially allows pupils to develop their learning, creativity and innovation in not only through a digital medium but also in visual contact with the teacher; face-to-face learning. Digital games are a type of interactive technology that can foster the learning process effectively and interestingly especially among young learners (Zin, Jaafar & Yue, 2009). Digital game-based leaning is a new approach to utilize the game as a medium for conveying learning contents. Van Erk (2006) claimed that a game embodies well-established learning contents, principles and models of learning which will effectively make the learning context more meaningful. Children learn by directly relating to their environment in which they learn and demonstrate it, therefore, the learning that occurs is not only relevant but applied and practiced within the context.

By comparing with traditional learning like lectures and questioning, the traditional teaching methods are too conventional and do not provide pupils the opportunity to develop mathematical concepts and knowledge (Pili & Aksu, 2013), which are no longer appropriate for pupils' learning. Teaching Fraction with no emphasis on conceptual learning and only as an operational knowledge (Lee & Boyadzhiev, 2013; Van de Walle, Karp & Bay-Williams., 2012) is usually a part of the traditional teaching methods. In fact, the concept of fraction has multiple meanings and pupils' misconception of taking numerators and denominators as separate numerical values had caused them to achieve lower scores in their assessments (Van de Walle et al., 2012). According to the study of Pilli (2008), he had examined the effects of using technology in Fraction. He further reported that by using technology in his teachings, he had successfully improved his pupils' scores Fraction. However, there are very few studies in examining the relationship between the digital game-based learning and there is no study on this topic especially in Fraction that involves SJKC Year Four pupils. Therefore, SJKC Year Four pupils were selected as the sample of the study with the aim to examine the effectiveness of digital game-based learning approach to enhance pupils' achievement in Fraction.

The second critical issue is pupils demonstrate lower performance in items of Fraction in the international assessment, particularly in the primary and secondary levels of Fraction. In this study, the mathematical learning content of fraction was chosen because it was first introduced in Malaysia's curriculum in primary Year 1 (Ministry of Education, 2013). Numerous studies have shown that researchers have consistently commented on the huge percentage of individual lacking basic fraction concepts and knowledge especially in Malaysia, our pupils are struggling with Fraction both in primary and secondary schools (Idris, 2011). At the early stages of learning mathematics, pupils in primary and secondary school have been taught to learn the concept of Fraction and ways to compute with Fraction, however they still make significant errors in the operations such as addition and subtraction that involved Fraction (Suhaidah, 2006).

Since fraction is important to Malaysian primary and secondary school pupils, it is time to reveal our pupils' poor performance in the aforementioned international assessment. In the past two decades, the international assessments, such as Trends in International Mathematics and Science Study (TIMSS) has merged as a means to compare the quality of educational systems across different countries (Tan, Ismail, & Abidin, 2018). TIMSS is aimed to assess pupils in Grade 4 (equivalent to Malaysian Primary Year 4) and Grade 8 (equivalent to Malaysian Secondary Form 2) on three different cognitive domains such as knowing, applying and reasoning. In the recent TIMSS report (2015), it had reported that Malaysia only participated for the eighth grade. The average Mathematics score of Malaysian eighth graders in TIMSS was 465 point, which was far below the TIMSS scale's central point of 500. Besides that, only 32% of our Malaysian pupils could correctly answer tasks related to the topic of Fraction based on the TIMSS (2015) report. Therefore, it is necessary to analyze what were the possible errors that caused pupils' low performance in Fraction, especially mathematical problems that include equivalents, comparisons, partitioning, and word problems in the operations of fraction.

Based on the analysis of TIMSS (2015) 8^{th} grade mathematics International Result by Mullis, Martin, Foy and Hooper (2015), our Malaysian pupils were weak in identifying equivalent simple Fraction. One of the sample questions was related to equivalent expression, which is to find the unknown value when $\frac{4}{14}$ and $\frac{(\ )}{21}$ are equivalent? Only 49% of Year Four pupils can answer this task correctly, which means more than half the pupils could not find the correct answer for the unknown value. According to Mullis et al., (2013), this type of question is focused on measuring the cognitive domain of application among the pupils to test their ability to apply the conceptual understanding in various problems. This result had clearly shown that our Malaysian Year Four pupils were weak in equivalent Fraction and they made significant errors in answering the questions.

Another type of fraction question from the Analysis of TIMSS (2015) 8th grade mathematics Concepts and Released Mathematics Items (2015) also reported that our Malaysian pupils demonstrated poor understanding of fraction in providing reasons for fractional parts of a whole in a word problem. There were only 7% Malaysian pupils who were able to achieve a score of at least 50% correct, whereas the other pupils failed to provide appropriate reasoning in the given task. This type of question is focused on measuring the cognitive domain of reasoning with the aim to test pupils' ability to provide reason in non-routine problems with complex contexts that requires multiple steps (Mullis & Martin, 2013). It is then revealed that Malaysian primary school pupils only possessed basic mathematics knowledge, however, they lacked skills in answering the "applying" and "reasoning" questions (Ministry of Education, 2013). Therefore, the report had given the researcher an alarming fact that there is a strong need to enhance Year Four pupils' achievement in fraction (equivalent, comparisons, partitioning, and fraction operations) in order to know, apply and reason in various problems that include routine and non-routine problems.

The third issue is the lack of studies in the area of using digital game-based learning in enhancing Year Four pupils' achievement in fraction. Based on the study of Larkin (2015), digital game-based learning through application is a new concept of learning that will be the next big thing in our education system. In another study, Brown et al., (2009) explained that the way of presenting digital game-based learning through application could affect pupils' achievement in fraction. For example, a digital game that allows pupils to play according to their abilities and adapt to the difficulties of each game level, it could be helpful to engage pupils in learning Fraction (Brown et al., 2009). Similarly, Simsek (2016) also reported that digital game-based application could provide a positive learning environment which enables primary school pupils to perform better in fraction at their own pace without much guidance from the teacher. There were also many previous studies that had revealed the use of digital game-based application on promoting pupils' interest and engagement in learning fraction. Moreover, it has not been reported whether the Year Four pupils' achievement in fraction can be improved with those applications (apps) especially in primary schools.

The digital game-based learning that was in this study is known as Zapzapmath application (apps). Zapzapmath app is an educational digital game for Kindergarten students and Year 1 until Year 6 pupils. The Zapzapmath app game features over 180 mathematical games that contain over 180 maths subtopics. Pupils can play Zapzapmath app through online mobile apps or on computers as it can be accessed anywhere or anytime. Zap Zap Math Apps encourages pupils to apply mathematical concepts and knowledge to make practice and then solve the mathematical problems (Zapzapmath Online, 2018). A digital game-based application like Zapzapmath app provides rich learning objective and content which aligned with the Common Core State Standard (CCSS) which also helps pupils to gain motivation and enhances engagement in gaining new knowledge and skills through playing digital games (Gros, 2015).

Moreover, Lowrie and Jorgensen (2015) stated some of the advantages of implementing digital game-based application are promoting pupils' mathematical thinking and reasoning and developing positive attitudes in learning mathematics. Besides that, Gros (2010) emphasized that by applying digital game-based applications such as Zapzapmath app could help pupils construct and develop new knowledge and also improve pupils' interest and motivation in learning mathematics, especially in Fraction. Zapzapmath app can be used as a modern teaching and learning tool in classroom to facilitate the learning of mathematics. Every section of the game trains accuracy, speed, and provides missions in which pupils get a chance to practice their skills to solve mathematical problems quickly or complete a task without mistakes through playing the games. Furthermore, Zapzapmath app promotes efficiency in introducing the concept of mathematics and improves pupils' achievement in fraction (Gros, 2010).

Over the last two decades, there were few studies that suggested that digital game-based application works in learning mathematics (Divjak & Tomic, 2011; Hung, Huang & Hwang, 2014; Stienstra, 2014; Logan & Woodland, 2015). According to (Kickmeier-Rust, Mattheiss, Steiner & Albert, 2011; Westera, 2015; Mercer, Kythreotis, Robison, Stolte, George & Haywood, 2016), most researchers focused on the investigation of motivation, engagement, attitudes and anxiety towards the use of digital game-based learning through applications. Unfortunately, there was none done on the effectiveness of digital game-based application such as the Zapzapmath app to enhance pupils' achievement in Fraction, especially in an elementary level. Those studies only focus on how digital game-based learning brings fun, motivation and engagement in learning mathematics and the ability to solve mathematical problems. It is also not clear whether the use of digital game-based learning application like

Zapzapmath app can be used to improve Year 4 pupils' achievement in fraction, which lead to the research gap of this study – the pupils' achievement in Fraction and the effectiveness of using digital game-based application.

In Malaysia, a limited number of applications of digital game-based learning in Fraction is a concern. According to the study of Hussain, Hoe and Idris (2017) they pointed out that the lack of digital game-based learning (DGBL) in learning mathematics is a critical problem in the present-day Malaysian educational environment. It is important to promote digital game-based learning as medium of learning in order to help Malaysia pupils' gain better understanding of mathematical knowledge in this 21st century. At the same time, it is an important and challenging issue to propose a new learning approach to help enhance pupils' performance in Fraction. Therefore, in this study, there is a need to investigate the effectiveness of digital game-based learning in enhancing Year Four pupils' achievement in Fraction.

1.3 Theoretical Framework

According to Nazirah, Talib and Norishah (2013), applying learning theories and strategies in developing any medium of learning instruction including game is necessary. When the games were developed based on strong educational theories, it would help increase the potential of games and impact pupils' learning all the time (Lester, Spires, Nietfeld, Minogue, Mott & Lobene, 2014). The theoretical framework of this study was guided by the cognitive information processing theory. This information processing theory was developed by Robert M. Gagne in 1965 as a model of cognitive learning theory (Gagne, 1985). Cognitive Information processing theory defined learning as a series of transformation of knowledge as it passes through various levels in a person's mental mental (Lester et al., 2014). According to Shuell (1986), cognitive information processing theory stresses on how people participate in environmental events, encrypt information to be acquired and connect it to knowledge in memory, accumulate new knowledge in memory then recover it once needed.

The principle of cognitive information processing theory is as follows: “Humans are processors of information and the mind is an information-processing system. Cognition is a series of mental processes. Learning is the acquisition of mental representations.” (Mayer, 1996, p. 154). Mayer (1996) further explained that people select and attend to features of the environment, transform and rehearse information, relate new information to previously acquired knowledge to make it meaningful.

According to Schunk (1996), he mentioned that cognitive information processing theories are essential and how it functions, but it shares some common assumptions. One of the assumptions is that information processing takes place in stages that occur unexpectedly between receiving a stimulus and producing a response. Then, a consequence is that the form of information, or how it is represented mentally, varies depending on the stage, and the stages differs qualitatively from each other (Shuell, 1988).

The second assumption stated that the information processing is similar to computer processing (Shuell, 1996). The human system operates analogous to a computer for example collects information, saves it in memory and retrieves it when necessary. Moreover, researchers (Barsalou & Hale, 1993; Gagne & Medsker, 1996; Cunnigham, Zelazo, Packer & Van Bavel, 2007) presume that information processing is comprised of all cognitive activities like perceiving, rehearsing, thinking, problem solving, remembering, forgetting and imaging. Since the cognitive information processing theory is going to be used as the theoretical framework of the study, therefore the Chapter 2 will discuss even further about cognitive information processing theory.

Besides that, this study also utilized the micro theory of Gagne's conditional learning theory as the underlying theory of cognitive information processing learning. Conditions of learning theory describe different levels of learning as an instructional design that allow the interactions and environmental stimuli to bring about change in the cognitive structures and operations of the learner (Gagne et al, 1992).

There are nine events of instruction which play important roles to activate processes for effective learning (Gagne, 1985). It is a systematic conditional with nine events of instruction in order to help pupils enjoy the learning process in a meaningful way. Gagne believed that all lessons should include a sequence of events. Most importantly, the basic concepts must be understood by learners first before moving to the higher level. Hence, the learner could follow this instruction as simple steps to get desired outcomes.

There are nine events of instructions suggested by Gagne (1985) when transferring the knowledge to learners. The nine events can be reframed as follows (Gagne, Wager, Golas & Keller, 2005) as shown in Table 1.1.

Table 1.1

Nine events of instructions by Gagne's Conditional Learning Theory

Instruction 1 : Gaining attention (reception)
↓
Instruction 2 : Informing learners of the objective (expectancy)
↓
Instruction 3 : Stimulating recall of prior learning (retrieval)
↓
Instruction 4 : Presenting the stimulus (selective perception)
↓
Instruction 5 : Providing learning guidance (semantic encoding)
↓
Instruction 6 : Eliciting performance (responding)
↓
Instruction 7 : Feedback (reinforcement)
↓
Instruction 8 : Assessing performance (retrieval)
↓
Intstruction 9 : Enhancing retention and transfer (generalization)

The reason of choosing Gagne's conditional learning theory based on the cognitive information processing is because it provides a nine-step sequence that can be used to guide, adapt and apply in the design and construction of digital game-based learning as a learning tool. Furthermore, how Gagne's conditional learning theory correspond to the cognitive processes and how it can turn to support digital game-based learning can be summarized in Table 1.2.

Table 1.2

Summary of the relationships of Gagne's conditional learning theory correspond to cognitive information processes theory

No.	Gagne's Conditions of learning	Corresponding Cognitive Information Processes theory	Features Supported in Games Based Application
1.	Gaining Attention	Reception of patterns of neural impulses	Provides animation and sound effect
2.	Informing Learners of the Objectives	Activating a process of executive control	Provides instructions in the game activates and how to win the game to achieve the objectives
3.	Stimulating recall	Retrieval of prior learning to working memory	Introducing different levels of difficulty in the game. The game from simple to complex levels.
4.	Presenting the stimulus	Emphasizing features for selective perception	Arranging and presenting learning content to motivate and challenge the learners according to their level of ability
5.	Providing learning guidance	Semantic encoding; hints for retrieval	Offering hints to guide learners in a game.
6.	Eliciting performance	Activating response organization	Proving interactivity in a game.
7.	Feedback	Establishing reinforcement	Presenting awards. Encouraging learners to the next/higher level
8.	Assessing performance	Activating retrieval making reinforcement possible	Assessing the level of progress made in playing the games
9.	Enhancing retention and transfer	Providing hints and strategies for retrieval	Enabling transfer of knowledge between levels and games.

Source: Mayer (1996) and Gagne, Wager, Golas & Keller (2005)

Based on the discussion of learning theories about cognitive information processing theory and Gagne's conditional learning theory, the summary of the relationships Gagne's Conditional Learning Theory was clearly presented in Table 1.2. It can be concluded that the Gagne's conditional learning theory has a greater range of learning aspects and a number of features that supports the design of digital game-based learning. Therefore, it would be the most compelling theory to guide the Zapzapmath application as a digital game-based learning approach in enhancing Year Four pupils' achievement in fraction.

In a conclusion, this theoretical framework is designed based on the cognitive information processing theory and Gagne's conditional learning theory. This theoretical framework is also used in learning Mathematics, especially in the topic Fraction such as identifying Fraction, equivalent Fraction, comparing Fraction and operations involving Fraction like additions and subtractions in order to improve pupils' achievement in Fraction. When the pupils are able to gain new knowledge from Zapzapmath app, it would be the preferred theory in guiding pupils to achieve better performance from the games.

The researcher used cognitive information processing theory and Gagne's conditional learning theory as theoretical framework to enhance pupils' fraction skills with using Zapzapmath app as a digital game-based learning tool. Hence, the cognitive information processing theory and Gagne's conditional learning theory are suited to be used as a framework to direct this study. Based on the theoretical framework, the researcher made some basic assumptions for this study, such as:

1. Year Four pupils are learning Fraction actively; they have been using digital game-based learning before this study was conducted.

2. Year Four pupils will make their best effort to complete the instructional activities and post-tests without any help from others.

3. Fraction knowledge built by pupils based on his or her own experience.

4. Year Four pupils' achievement in Fraction can be measured by using instructional activities and post-test given.

5. The pupils in both the experimental and control group have similar family background that would not help them to complete the task or interrupt what they are learning during the intervention period.

6. Year Four pupils score higher in fraction achievement test through the nine event of instructions with using digital game-based learning whereas the pupils in control group score higher through traditional teaching method with only textbooks and worksheets.

7. During the process of intervention, the researcher assumed the pupils in the experimental group require a longer time to adapt themselves to get used to digital game-based learning as compared to traditional learning. While pupils in the control group would not need a longer time to adapt themselves in traditional learning since they were usually taught in the same way in school.

8. During the process of analyzing the data obtained, the researcher assumed that the pupils in the experimental group would get at least 15 out of 20 items correctly in the pre and post-test given.

These assumptions are crucial in this study to help the researcher narrow down the scope of the research and ensure a smooth process of the research. Besides that, the assumptions can be used to help the researcher collect and analyze the data as well as to answer the research questions of this study.

1.4 Objective of the Study

The aim of the study is to investigate the effectiveness of using digital game-based learning in enhancing pupils' achievement in Fraction, which is focused on Primary Year Four pupils. In order to achieve that, the objectives of the study include:

1. To examine the improvement between pre-test and post-test of fraction achievement in the control group of Year Four pupils.
2. To examine the improvement between pre-test and post-test of fraction achievement in the experimental group of Year Four pupils.
3. To examine if the fraction achievement of the experimental group in the post-test is greater than the control group.

1.5 Research Question

The study aimed at answering the following research questions:

1. Is there any significant improvement between pre-test and post-test of the Year Four pupils' control group fraction achievement?
2. Is there any significant improvement between pre-test and post-test of the Year Four pupils' experimental group fraction achievement?
3. Is the fraction achievement of Year Four experimental group pupils in the post-test significantly greater than the control group pupils?

The level of significance used in this study was 5% or 0.05. Based on the research question stated above, the research hypotheses were made as below:

1. H_0: The mean of the post-test scores and the mean of the pre-test scores of Year Four pupils in the control group are not different.

   H_1 : The mean of the post-test scores is greater than the mean of the pre-test scores of Year Four pupils in control group.

2. H_0: The mean of post-test scores and the mean of the pre-test scores of Year Four pupils in the experimental group using Zapzapmath application are not different.

   H_1 : The mean of post-test scores is greater than the mean of the pre-test scores of Year Four pupils in experimental group using Zapzapmath application.

3. H_0: The mean of post-test fraction achievement of Year Four experimental group pupils and the control group pupils are not different.

   H_1 : The mean of post-test fraction achievement of Year Four experimental group pupils is higher than the control group pupils.

1.6 Operational Definitions

Achievement in Fraction

Achievement is defined as an indication of how much the participants benefited from this study (Belgin & Esen, 2017). The dependent variable in this study – achievement in Fraction is defined as the achievement level that ranks from Level 0, Level 1, to Level 2. Low achievers are pupils who were unable to answer eight out of 10 items correctly for item 1 to item 10, were graded as Level 0. Next, the pupils who answered eight out of 10 items correctly for item 1 to 10 were assumed to have mastered the visualization level of fraction concept which is Level 1. High achievers are pupils whose final level is 15 or above in over a total of 20 items in the fraction achievement test were assumed to have mastered the analysis knowledge level in fraction which is Level 2.

Digital game-based learning

Digital game-based learning (DGBL) is defined as the use of electronic games to foster teaching and learning effectively and interestingly (Gros, 2010). In addition, DGBL is a new paradigm which utilizes the game as a medium to convey the learning contents, uses the power of electronic games to captivate and engage users for a specific purpose such as to develop and to teach new skills or knowledge (Zin, Jaafar & Yue, 2009). By the end of game playing session, pupils are expected to achieve specific learning objectives and goals. Pupils' achievements can be accessed during a game play or at the end of game playing session (Nazirah, Talib & Norishah, 2013).

Fraction

The term fraction refers to common Fraction, and not related to concepts in working with decimals, percentage, ratio or proportion (Misquitta, 2011). In this study, fraction is presented in a game that involves four subtopics such as part-whole fraction, equivalent and partitioning fraction, comparing fraction and operations of fraction including addition and subtraction. Besides that, fraction is measured using the Fraction Achievement Test as an instrument.

Each subtopic is defined clearly in this study as below:

(a) Part-whole fraction. The term of part-whole fraction refers to the relationship between a part and a whole (Behr et al., 1983). In this study, the part whole fraction is measured using items No. 1 to No. 5 in the Fraction Achievement Test instrument.

(b) Equivalent and partitioning fraction. The term of equivalent fraction means Fraction that are equivalent in the same part to a whole relationship (for example $\frac{1}{2}$ is equivalent to $\frac{2}{4}$) have different names for the same value (Erdem, Gokkurt, Sahin, Basibuyuk, Nergiz & Soylu 2015). Partitioning fraction refers to when the whole or unit partitioned into equal-sized portions or fair shares (Martin et al., 2015). In this study, the equivalent and partitioning fraction is measured using items No. 10 to No. 14 in the Fraction Achievement Test instrument.

(c) Comparing fraction is the term that refers to comparing fraction magnitude between two Fraction by finding a common denominator (Mack, 1995). It also can be defined as a quantitative notion of rational number; that is, their ability to determine which of the relations, *is equal to*, *is less than* or *is greater than* (Behr et al., 1992, p.

324). In this study, comparing fraction is measured using items No. 6 to No. 9 in the Fraction Achievement Test instrument.

(d) Fraction operations involves addition and subtraction. The term of addition and subtraction of fraction means the before fraction is added or subtracted, the denominator must be the same (Lamon, 1999). In this study, fraction operations is measured using items No. 15 to No. 20 in the Fraction Achievement Test instrument.

Traditional Approach

Traditional approach is defined as pupils taught using standard, pencil-and-paper method of computation by teacher demonstration followed by pupils' individual practices (Newstead, 1998). The implementation of this traditional method focuses on developing meaning and understanding instead of procedures without connections to the concepts itself (Franco, Sztajn, & Ortigao, 2007). The teacher is the knowledge dispenser, and the pupils know mathematics when they can memorize and apply the given rules without understand the real meaning behind of the concepts (Lampert, 1990). This traditional approach in this study emphasizes algorithms and procedures for answering mathematical questions related with the topic of Fraction.

Zapzapmath application

The co-founder of digital game-based mathematics learning system – Zapzapmath application is John Ng, a Singaporean-based math teacher, who found out that there is a learning gap between education and technology. He then builds up Zapzapmath with a team of experienced developers and educators to bring a gamified way of math learning in education. Zapzapmath application is an educational mobile app or digital game-based learning tool that was designed to help elementary school pupils from

Kindergarten to Grade 6 to have fun learning mathematics in an engaging and effective way (Zap Zap Math, 2018). The Zapzapmath application is available for free download (trial version) from www.zapzapmath.com from the Google Play Store. Besides that, the Zapzapmath application can also be played online using personal computers to access all the games. The games apps provide over 180 math lessons for pupils to practice mathematical knowledge and skills. However, in this study, the researcher only focuses on the topic of Fraction, with certain subtopics including (a) part-whole Fraction, (b) equivalent and partitioning Fraction, (c) comparing Fraction, and (d) fraction operations involving addition and subtraction.

1.7 Limitation and Delimitations of the Study

Every study, no matter how well it is conducted, there must be some limitations and delimitations. In this study, there are three limitations in the aspects of research design, data collection method, and instrument whereas the three delimitations are related to mathematical learning content, sample and game apps used in this study.

The first limitation is research design. The research used a quasi-experimental design. The pupils were not assigned to the experimental group and control group randomly. The weakness of a quasi-experimental study is the lack of randomization which can limit the generalizability of the result to a larger population Webster (1985). Besides the lack of randomization, it also reduced the internal validity, conclusions about the causality in a quasi-experimental study (Creswell, 2013).

Secondly, there is limitation in the data collection method. The researcher taught the experimental group using technology while the control group was taught using traditional teaching approach. The data collected were subjective in nature as it was all responded by pupils. The researcher collected the data through the pre-test and post-test. Consequently, there might be bias to the validity of the data.

The third limitation is the instrument used in this study. The instrument is used to evaluate the result of the study. In this study, the only instrument used was Fraction Achievement Test. The items in the fraction test was adapted from National Assessment of Educational Progress (National Assessment of Educational Progress, 2014). These items were able to reflect pupils' fraction achievement in the topic of Fraction. Their achievement in Fraction would be identified based on the number of items answered correctly in the test.

However, to overcome the threat of internal validity, the pre-test must be given to both experimental group and control group before the intervention begins. From the results of the pre-test, pupils' initial achievement in Fraction was identified and compared. Besides that, the instructional module for the experimental group was planned systematically and checked continuously to avoid any mistakes during the process of collecting, analyzing and interpreting data. In addition, the validity of the instrument was checked by experienced lecturers and more than one experienced teacher who worked more than 15 years in teaching mathematics in primary school. Lecturers from a Teachers' Training College in Malaysia evaluated the data collected and the results were improved from lecturer's feedback and comments.

The first delimitation is related to mathematical learning. The researcher narrowed down the scope of learning to Fraction only which includes subtopics like part-whole fraction, equivalent fraction, comparing fraction and operations of fraction such addition and subtraction. However, there are few mathematical topics that were not investigated in this study such as whole numbers, decimals, percentages, time, money, geometry, probability and statistics.

In the aspect of samples used in this study, the researcher only selected Year Four pupils as respondents. This is because Year Four pupils have not learned some of the basic knowledge and skills in the topic of Fraction. For example, some subtopics like fraction operations are not yet introduced in Year 1 to Year 3 syllabus. Therefore, Year Four pupils are selected as respondents in this study.

The third delimitation is the game app used in this study. This study selected Zap Zap Math Apps as the digital game-based learning tool. This is because the Zap Zap Math Apps contains 150 games that covers 180 math subtopics and it can be downloaded from the Google Play Store for free trials. There are hundreds of games that were designed for pupils to practice mathematical knowledge with increasing level of difficulty to train their critical thinking skills and problem-solving skills in the process. As compated to the other apps, this app also provides a Web Dashboard for teachers and parents to track their children's individual performance via a report-card system and identifies which areas the children needed to give extra attention. Therefore, the selected game app in this study was also supported and evaluated by the supervisor with the aim of investigating its effectiveness in enhancing Primary Four pupils' achievement in Fraction.

1.8 Significance of the Study

Nowadays, the integration of technology in the field of education is very important. This is because the use of technology is becoming increasingly popular in schools at different levels of education such as primary education, secondary education and tertiary education. Such integration helps to create an effective learning environment with the presence of technology (Akgul, 2014). The integration of technology used in this study was implemented through the digital game-based learning approach to facilitate the learning of fraction more effectively in the mathematics classroom. The present study can contribute a new insight in the teaching and learning of Fraction to various parties such as mathematics teachers, students, lecturers and curriculum developers. Every party has the responsibility to make such a change in order to be in line with the current curriculum shifts.

In the research of Ertmer and Ottenbreit-Leftwich (2014), they discussed that teachers' mindsets must change to include the idea that "teaching is not effective without the appropriate use of information and communication technologies (ICT) resources to facilitate student learning" (p. 255). For many decades of research conducted in field of education, the role of the teacher in school is not only for the purpose of chalk and talk, they are encouraged to use new supportive approaches or teaching strategies with the help of technology in the teaching and learning environments. This study is useful for teachers to teach using digital game-based learning as learning tool to teach the topic of Fraction. The activities and lessons from this study can provide teachers some insights about game-based apps used in the mathematics classroom. Teachers can refer to the ideas from this study to design appropriate activities and lessons in order to encourage students to use the game-based apps using their mobile devices to learn mathematics creatively. Besides that, teachers can also plan interesting lessons or activities with the use of game-based apps to develop their interest to learn mathematics and enhance their mathematics achievement, especially weaker students. Therefore, this study is not only useful for teachers at school but also beneficial to all students who expects to master the conceptual knowledge and skills in learning the topic of Fraction.

This study is also important for college or university lecturers to train future teachers to use digital game-based learning apps to teach mathematical concepts and knowledge. For example, teachers can be trained to focus on specific topics, like teaching the topic of Fraction by integrating game-based learning apps to develop new ideas of teaching mathematics in school. When teachers are trained in advance to adapt with new teaching approaches, they would apply these approaches to teach or coach pupils to learn the concept of mathematics more innovatively and creatively. Therefore, the findings of this study are would provide a new source of idea to instructors to train future teachers to implement new learning tools effectively in mathematics classroom.

Curriculum developers can make this study as a recommendation for improvement in the curriculum as the role of curriculum developers is to design and develop creative modules or new syllabus with the integration of technology to strengthen teacher's teaching skills. With appropriate and useful training modules, teachers can be trained to use of digital game-based apps in classrooms and ensure that all recommended teaching materials or training lesson is effective for teachers and students. The Ministry of Education can also make changes to provide teachers with the skills of teaching mathematics using technology and at the same time, to ensure that all the teaching materials and skills that the students would learn is in line with the current curriculum standards in Malaysia. Therefore, teachers who gained appropriate training in a service are able to improve their pedagogical knowledge and also improve pupils' achievement in learning mathematics.

1.9 Summary

The experimental study aims to investigate the effectiveness of a digital game-based learning in enhancing Primary Four pupils' achievement in Fraction. This study contains background of the study, problem statement, theoretical framework, research objectives, research questions, operational terms, limitations, delimitations and significance of the study. Critical issues of the study were highlighted in the background of this study which were described and justified. Theoretical framework, research objectives, research questions and research hypotheses were explained clearly in each part. Next, the operational term for this study was stated. Possible limitation, delimitation and significance of study were also explained in this study. Chapter one serves as a basic report in the research. With that, a literature review is discussed briefly in Chapter Two, research methodology in Chapter Three, the findings of the study are shown in Chapter Four and finally, the discussion, conclusions and implications of the study are shown in Chapter Five. Lastly, all the references are listed under References. The supporting documents or materials of this study are attached in the Appendices.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

In chapter 2, we will justify the use of Cognitive Processing Informative Theory and Gagne's Conditional's learning theory as the basis in this research. Besides that, the conceptual framework and past researches which observed digital game-based learning especially in the topic of fraction as well as the teaching methods were discussed. Some previous studies related to the traditional approach and using Zapzapmath app as digital game-based learning approach will be shown. There is also a section discussing the benefits of using digital game-based learning in education and how digital game-based learning can be used in enhancing pupils' achievement in Fraction. Previous research has been done to investigate how digital game-based learning improve pupils' achievement in mathematics. Moreover, the content and features of the Zapzapmath app will also be discussed briefly in this chapter.

2.2 Cognitive Information Processing Theory

Cognitive Information processing theory defined learning as a series of knowledge transformation as it passes through various levels in a person's cognition. According to Cunningham et al. (2007), information processing theorists suggested the learners must know certain prerequisite information and the new information should be demonstrated to them in a way that facilitates encoding (input). By gaining a better understanding of how information is processed, pupils need to acquire, store and retrieve the knowledge, so that a meaningful information is created to make it easier for pupils to remember and learn more systematically and efficiently in the. Besides that, Barsalou and Hale (1993) described that this learning theory involves human cognitive system is similar to a computer in the learning processes. He explains how information progresses from input sensors (encoding) and through encoding procedures to be stored (storage) and recalled from memory (retrieve the information) when necessary.

Gagne and Medsker (1996) further explained that the information which is attended to transfer through the main three stages, accordingly to sensory memory, short-term memory and long-term memory. A sensory memory is holding all sensory input (light, sound, smell, heat, etc) to gather the information from the environment in a short period of time. As its storage capacity is very limited, it is absolutely critical for learners who attend to the information at this initial stage to transfer it to another next stage. Without a learner's attention at the cognitive processing information process, learning does not occur (Gagne, 1985). Therefore, a learner' attention in learning process is necessary to help them enter the short-term memory. A short-term memory holds information in conscious awareness as it happens quicker and involves information that is not learned as well. When the pupils learn the information in a short term of period, they will soon forget unless it is repeated (maintain rehearsal) over and over again. The longer the information works in short term memory, the greater the chance to help pupils develop information in the stage of long-term memory, which is the final memory in information processing.

After the meaningful information is encoded into long term memory through rehearsal, there are two types of knowledge which are accepted and stored – declarative knowledge and procedural knowledge. Declarative knowledge is specific information about rules, definition, procedures or facts, while procedural knowledge is information required to be able perform in a given task (Eggen & Kauchack, 2007). By comparing with previous stored memory, long term memory has unlimited capacity to store information. When pupils learn new information by relating to prior knowledge, it will help to promote multiple connection between the new and prior knowledge. Pupils who are able to relate the new information with the information already stored in memory, it will be easier for them to remember and learn information more effectively.

2.3 Gagne's Conditional Theory

This study utilized the micro theory of Gagne's conditional learning theory as the underlying theory of cognitive information processing learning. In the research of Gagne et al (1992), conditions of learning theory describes levels of learning as an instructional design that should allow the interactions and environmental stimuli to bring about change in the cognitive structures and operations of the learner. The Gagne's learning theory recognizes as a complex process of learning (Case & Bereiter, 1984) and therefore learning does not only stress on the physical behaviours and simple stimulus response connections. But most importantly, it should focus on the learning of concepts, rules, principles, intellectual skills and cognitive strategies.

According to Case and Bereiter (1984), they further explained that Gagne's theory had brought a paradigm shift beyond the behaviourist and cognitive theory is a concept of sequencing intellectual skills. It allows the instruction to move to higher order skills when developing in prerequisite skills. Gagne's conditional learning theory is the most compelling as it is designed based on the learning outcomes that follow the instructional strategies to utilize the learner's outcomes while analysing the content based on the learner's expectation (Richey, 1986).

According to Robert Gagne (1985), there are nine events of instruction plays important role to activate processes for effective learning. It is a systematic conditional with nine events of instruction in order to bring out the learning process in a meaningful way. Gagne believed that all lessons should include a sequence of events and the basic concepts must be understood by learner first before moving to the next level. Therefore, the learner can use this instructions as simple steps to follow the process to get a desired outcome. There are nine events of instructions suggested by Gagne when transferring the knowledge to learners. However, Beaker (2005) argues that the Gagne's conditional learning theory with nine events can be reframed so that the instructional design can be applied in the design of computer games as learning tools. The nine events can be reframed as follows (Gagne et al, 2005).

Instruction 1 : Gaining attention (reception)

A learner is ready to learn and participate in a game. This is called as "attract modes". This mode appears to be an introductory mode in a game. It is important to capture the learners' attention when they start playing a game. The game's introduction would give clear explanations such as rules and goals. This mode would provide interesting animation and audio effects to motivate the learner to play the game.

Instruction 2 : Informing learners of the objective (expectancy)

This section of a game is to inform the learner of the learning objectives to help them understand what they are going to learn during the game and how to achieve the goal by winning the game. It is a must to provide objectives before the game begins. When the learner understands the learning objectives, it could motivate the learner to complete the game.

Instruction 3 :   Stimulating recall of prior learning (retrieval)

In this section, the learner is provided with information about what they have already learnt and continue developing new knowledge during game-play. This allows the learners to retrieve and reconstruct their existing knowledge. In order to achieve this, levels of game-play are introduced in the game environment where the learners are well aware of the progression of the game-play through the concept of levels. Stimulations of recall can be done through the animation of the graphical elements presented in games. At this stage, remembering information with organize thoughts allow learners to make sense of new information by relating them to what they have already experienced.

Instruction 4 : Presenting the stimulus (selective perception)

A game presents the skills of a lesson through effective and efficient instruction. Before a game starts, a tutorial will be introduced to give a learner clear explanation. This also allow learners to receive instruction on each individual task. Therefore, the information given could help learners to understand each level by its difficulty and challenge. Appropriate challenges are part of the game environment to ensure learners be motivated through the game-play.

Instruction 5 : Providing learning guidance (semantic encoding)

This instruction refers to a demonstration of an example like a hint or tutorial to provide proper guidance for learners to help them learn the content effectively and smoothly. This section acts as a "help option" for the learners, in case they are either "lost" or confused during the game-play.

Instruction 6 : Eliciting performance (responding)

Interactivity is another important element that allows learners to be engaged with the game-play. This event requires learners to practise new skills, knowledge or behaviour. The purpose to elicit the performance is to confirm the learners have accurate understanding and repetition of concepts.

Instruction 7 : Feedback (reinforcement)

An immediate feedback of a game includes scores, displays, queries and verbal feedback. This element is important to the learners to help them access and facilitate learning. It also gives learners an indication if they are progressing towards their target. Therefore, appropriate feedback needs to be incorporated to ensure the learners are progressing well in the game-play.

Instruction 8 : Assessing performance (retrieval)

At this stage, learners demonstrated what they have learned through the game without any help, clue, hints or guidance. It is important to test learners if the expected learning outcomes have been achieved. For example, conduct a post-test to check learners' mastery of skills. Achievement in the game-play is an integral part of the game. Achievement need not to be easy but assessment must be logically tied to that achievement.

Intstruction 9 : Enhancing retention and transfer (generalization)

When a learner keeps repeating the same learned concepts, it is an effective mean of enhancing retention. It brings another meaning that the knowledge learnt in the game should be transferable and applicable in different situations. For example, learners play a single game, they need to remember the skills, strategies and also the knowledge from the previous level. When they master the skills, they are able to transfer new skills or strategies into other games. Hence, the more frequently they practise the skills, the more they apply the new skills into other games.

2.4 Conceptual Framework

The conceptual framework in Figure 2.1 illustrated the connections of the variables that helps in achieving the objectives of the study.

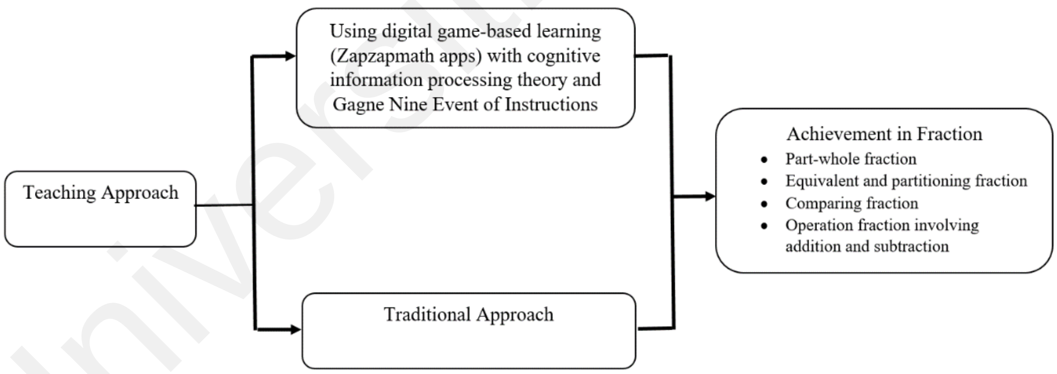

Figure 2.1. Conceptual framework for the study of Achievement in Fraction among Primary Four pupils using digital game-based learning

The process shown in Figure 2.1 represents how the study was carried out to determine the research outcome. The two variables are related to each other with the independent variables and dependent variables of this study. In this study, the independent variable is teaching approach as shown in the first column. Based on the figure, there are two teaching approaches. One of the teaching approaches is digital game-based learning (Zapzapmath app) which is in line with the Cognitive Information Processing theory and Gagne's Nine Event of Instructions. This approach is for pupils who were assigned to the experimental group. Pupils learned Fraction using the Zapzapmath app and instructional module based on the Cognitive Information Processing theory and Gagne's Nine Event of Instructions. The experimental group pupils received the treatment through this intervention for six weeks.

The other teaching approach is the traditional approach. This approach is for pupils who were assigned to the control group. Pupils in the control group learned Fraction only through textbooks and worksheets. The teacher delivered the knowledge using traditional pedagogy and the pupils attempted the distributed worksheets.

The dependent variable in this study is the subject that is measured, which is fraction knowledge and skills of Primary Four pupils. The pupils from both experimental and control groups were tested in a post-test after the interventions were done for the experimental group.

2.5 Fraction Knowledge and Skills

In this study, we focused on the learning of fraction knowledge or skills such as identifying the numerator and denominator of Fraction, comparing Fraction and fraction operations including addition, subtraction, multiplication and division. All these knowledge and skills are both important to learn with understanding as well as to apply new knowledge or skills in a new setting. Thus, pupils will be able to use the new skills or knowledge to do mathematics especially in the topic of Fraction.

In a formal fraction curriculum unit, pupils typically learn about Fraction by studying a set of concepts and procedures that are central to Fraction (McNamara & Shaughnessy, 2010). Research suggested that being able to solve problems of Fraction and apply new skills or knowledge in a new setting is closely related to how well both conceptual and procedural knowledge are developed (Mack, 1990; Hiebert & Carpenter, 1992). In the study of Aksu (2001), conceptual knowledge refers to understanding relationships that are integrated or connected to other mathematical ideas and concepts. Procedural knowledge is the knowledge of symbolism that is used to represent mathematics and the rules and procedures used in mathematics tasks. The research also further described that the goal of learning Fraction emphasizes that there must be an understanding of fraction concepts, which is a facility with the symbolism and methods of performing fraction processes and showing a clear connection between the corresponding concepts of methods and symbols.

However, there are several number of studies which have observed that pupils were facing difficulties in understanding Fraction because they learned Fraction through rote memorization of procedures without a connection between what is taught and their informal ways and means of operating (Post, 1981; Steffe & Olive, 2001; Olanoff et al, 2014). In the study of Aksu (2001), it has described deficiencies in pupils understanding of Fraction. For example, many pupils acknowledge and apply the procedural rules to carry out operations step by step like adding two Fraction, but they failed to explain the meaning of what ¾ + ½ represents. Such difficulties experienced by different age groups in mathematical operations with Fraction have been studied by several researchers (Mack, 1990; Mack, 1995; Pitkethly & Hunting, 1996; McNamara & Shaughnessy, 2010; Kaasila, Pehkonen & Hellinen, 2010; Lin, Becker, Byun, Yang & Huang, 2013).

When pupils lack the understanding of Fraction, this situation would become a common type error in teaching Fraction which means that the pupils began computation before they have conceptual knowledge and understanding of Fraction to perform such operations. As stated by Aksu (2001), pupils must understand the meaning of Fraction before they are to perform operations with them. In a previous study (Kaasila, Pehkonen & Hellinen, 2010), pupils with conceptual understanding were able to organise the mathematical ideas into a coherent whole. They further described that conceptual understanding also makes it easier for pupils to remember facts because it can be reconstructed when forgotten. Pupils can often understand the concept before they can verbalize or explain their understanding about the mathematical ideas they have learned.

A strong understanding of fraction concepts and procedures is a necessity in elementary grades before moving on to other rational concepts in later grades (Wilkerson, Cooper, Gupta, Montgomery, Mechell, Artebury, Moore, Baker & Sharp, 2015). This is further supported by Brijlall, Maharaj and Molebale (2011), which a conceptual understanding of Fraction and operations on them, as clearly distinct from the ability to successfully manipulate algorithms, is a necessary prerequisite if pupils are expected to make sense of their learning about Fraction. Further explanation by Bulgar (2003), suggested that pupils who are able to carry out algorithms procedurally do not necessarily have a deep understanding of the mathematics behind them. Furthermore, when problems do not fit exactly into the structure within which the algorithm was taught, even competent pupils can have difficulty to answer the problems given.

As a summary of the importance of fraction knowledge and skills, it is closely related to geometry, ratio, rates, proportion, and algebra. All these topics that pupils have learned in school are related to their daily activities. This powerful knowledge about the importance of concept of Fraction can help students apply their new skills or knowledge to make precise decisions and solve problems that happen in real life situations.

2.6 Problem Encountered by Pupils in Learning Fraction in Primary School

Fraction plays central role in our everyday life. However, a previous research had found that primary school pupils thought Fraction to be a very complex and a difficult concept to master (Bulgar, 2003; de Castro; 2008) and children struggle more to understand Fraction during learning mathematics (Olofson, Swalow & Maureen, 2016). Yet, students still failed to perform in their fraction assessment even though they had learned Fraction at the early age. According to Siegler, Fazio, Bailey and Zhou (2012), one of the difficulty is confusable relations among fraction arithmetic procedures. For example, when fraction addition and subtraction problems have the same denominator, the denominator is maintained in the answer, such as $\frac{1}{5} + \frac{2}{5}$ will be equal to $\frac{3}{5}$, but this situation is not the case for fraction multiplication and division. Furthermore, this confusion arises among the pupils about when and why common denominators are not same as fraction addition or subtraction. The report of Siegler et at. (2012) showed that pupils with this confusion tend to make errors when solving fraction multiplication and division, such as $\frac{2}{5}\ x\ \frac{3}{5}$ equal to $\frac{6}{5}$. Obviously, this study had proven that pupils found it difficult to master the concept of fraction operation that includes addition and subtraction.

In the study of Gokalp and Sharma (2010), they had done a research with twelve sixth grade pupils and twelve eighth grade pupils in Australia to understand the pupil's conceptual and procedural understanding of addition and subtraction of Fraction. They found out that most of the pupils do not try to understand the logic behind the fraction operation especially on addition and subtraction of fraction instead of memorizing the rules, formulas, algorithms and terms. For example, pupils have difficulty with adding or subtracting Fraction with unlike denominators or they may add or subtract the numerators and denominators separately and write the results instead of finding the equivalent of denominators and then adding the numerators. In order to overcome these difficulties faced by pupils, researchers used Pirie and Kieren's model (1994), which is a constructivist and dynamic process to encourage higher thinking abilities but not memorization. At the end, the results showed that some of the students had difficulty with questions like addition of Fraction with unlike denominators and figured it in a wrong way. Many students chose to use words to explain rather than use symbols. Even the study used hands on activities help pupils learn better and actively involved in the learning process by making connections, generalizations and solving problems, pupils still faced difficulty in understanding the more abstract concept in fraction operations.

Another common error found in the study of Newton (2008), pupils tended to add numerators and denominators (for example, ¼ + 1/6 = 2/10). As the pupils concluded that there were 2 shaded parts and 10 total parts when it comes to addition in the whole number concept. This incorrect procedural knowledge was linked to incorrect conceptual knowledge as well. Therefore, building a correct conceptual knowledge must use appropriate representations such as concrete or pictorial representations and things related to real life situations (Mack, 2001) will help students to construct different characteristics of fraction concepts and knowledge as well. According to Piaget (1976) in the study of Wilkerson et al. (2015), they stated that elementary pupils who engaged in learning abstract mathematical concepts such as fraction concepts and knowledge can be taught with accompanied by representations or concrete experiences to help pupils understand various fraction concepts. Although there are many fraction ideas, the focus of the study was on fractional domains of part-whole, portioning, fair share and equivalence. Since the concepts overlap, it might confuse pupils to connect the concepts and skills. Hence, the idea of using digital game-based learning as learning tool to help pupils develop the relationship between the various fraction concepts and knowledge is useful.

2.7 The Benefits of DGBL in Learning Mathematics

Digital game-based learning (DGBL) refers to the usage of the entertaining power of digital games to serve an educational purpose (Prensky, 2001). Digital game-based learning can be used as learning tools for pupils while engaging in learning Mathematics (Lowrie, 2015). There is increasing interest in the benefits of using digital game-based learning in Mathematics, as part of a larger enthusiasm for the potential of games environment, games design and pedagogy to support the learning in Mathematics (Lowrie & Jorgensen, 2015; Gros, 2015; Beavis, 2015). Besides that, various studies had explored that digital game-based learning in Mathematics can support students improving self-efficacy, learning motivation, anxiety and learning achievements (Hwang & Wu, 2012; Hung, Huang, & Hwang, 2014); promote collaboration, cooperation and interpersonal skills (Wong, Boticki & Looi, 2010); develop visuospatial reasoning skills, problem solving skills and decision making skills (Lowrie, 2015); increase pupils engagement and change in attitudes toward learning Mathematics (Van Eck, 2015). All these benefits of DGBL in learning Mathematics had been proven in those studies; perhaps it increased interest among educators to integrate the potential of DGBL into mathematics in order to develop a meaningful game environment as compared to traditional teaching methods.

In the study of Trybus (2009), the digital game-based learning were beneficial which includes these four key learning principles:

(1) Digital game-based learning provides immediate positive or negative feedback to players in a non-threatening situation and give reward to correct selection or clarify misconception. Through this process, players learned to increase and refine their prior knowledge about the concept which enhance their learning abilities (p.1).

(2) As the digital game-based learning gives immediate feedback to players, it helped to increase motivation to engage the game. Student's motivation affects both engagement in learning activities and retention of acquired knowledge and skills (p.1).

(3) Digital game-based learning provides students with the opportunity to practice learned skills by applying the prior knowledge based on the context of game and allow the student to develop mastery concept and knowledge (p.2).

(4) Digital game-based learning used the scores and rewards, offer feedback, learn the context of a game with specific goal. All these structures motivate students to engage in the game until the target is achieved and mastered. As these learning principles are applied in teaching and learning

> Mathematics, it benefits all the educators and pupils in twenty-first century (p.2).

There are several studies in Mathematics education that had identified a number of benefits associated with using digital game-based learning in Mathematics. Hwang and Wu (2013) had conducted a quasi-experimental study to investigate the benefits of digital game-based learning (DGBL) system for mathematics learning. Total of 56 grade two pupils from Taiwan participated in this study. An eight-week learning activity was conducted with the experimental and the control groups. During the intervention, the experimental group used the DGBL system with diagnostic mechanism, while the control group used the general DGBL system without diagnostic mechanism. Every week, the study was conducted with two 40-minute lessons for two groups in learning addition and subtraction. A pre-test and post-test were given to both groups to investigate whether the DGBL system gives a sense of satisfaction for students in learning Mathematics. The end result of the study showed that the mean of experimental group's post-test was 88.69, which is higher than the control group's 85.71. The result proved that there were significant improvement in the experimental group (using DGBL with diagnostic mechanism) which was better compared to the control group (using general DGBL without diagnostic mechanism). During the learning process, the Attention, Relevance, Confidence-building and Satisfaction (ARCS) questionnaire revealed that students who engage in learning Mathematics through DGBL methods are positively motivated. Therefore, the findings of this study had clearly reported that a proper digital game model integrated into mathematics learning by providing a diagnostic mechanism can effectively enhance interest in learning mathematics and reduce students' anxiety. While the anxiety of learning

Mathematics had been removed, both learning motivation and performance in Mathematics with DGBL could be enhanced.

Recent research of Hung, Huang and Hwang (2014) also conducted quasi-experimental research to investigate the effects of digital game-based learning on pupils' self-efficacy, motivation, anxiety and achievements in learning Mathematics. A total of 69 pupils in three classes were selected as subject study. They were divided into three groups and each group consist of 23 pupils, group A and group B were assigned as experimental groups, while group C was assigned as a control group. For group A, pupils learned using the DGBL approach, the ones in experimental group B learned through technology-enhanced learning approach; on e-books, and the control group C learned by the traditional instruction approach. During the experimental process, all three groups took pre-test, intervention and post-test. The experimental result showed that digital game-based learning effectively improved the pupils' learning achievements, learning motivation and self-efficacy as compared to the traditional instruction model. The discussion of this study also included the pupil's interview feedback, the reason of improvements in learning Mathematics with DGBL is because digital game-based learning able to attract the attention of pupils to engage them in mathematics practices. However, there was no significant difference found between the Mathematics anxiety in experimental groups. The results also showed that the mathematical anxiety in both experimental groups had decreased after the intervention, while the traditional instruction of the control group increased. This result also indicated that the use of DGBL have the potential in decreasing the mathematical anxiety of students. Therefore, researchers of this study suggested that it was worth developing and utilizing the digital mathematics game in future since it benefits students in which they gained higher learning achievements, motivation, self-efficacy and most importantly, it reduces pupils' anxiety in learning Mathematics.

In addition, digital game-based learning had been used to promote collaboration, cooperation and interpersonal skills (Boticki, Looi & Wong, 2010). Study of Boticki et al (2010) documented that using personal mobile devices as digital learning tools to promote collaboration in learning Fraction. To improve collaboration, cooperation and interpersonal skills, pupils were required to leave the comfort zone and extend their social circle to complete the task with the aid of mobile devices. Pupils have to collaborate with other people in order to merge (add) the fraction to form a full circle (a whole). During the learning activities, students had to do face-to-face discussions with their peers, reflect on their own Fraction, and work collaboratively in order to achieve the goal of having a full circle. The results of this study showed that pupils enjoyed the collaborative learning activity and were able to move over to communicate face-to-face with the aid of technological tools. Therefore, collaboration, cooperation and interpersonal skills in this study have been improve through well-designed learning activities and integrate the benefits of using DGBL in learning fraction.

A number of researchers have stated that an increase in pupil's engagement when used digital game-based learning is also one of the benefits for pupils (Rai, Heffernan, Gobert & Beck, 2009; Charles, Bustard and Black, 2011). In the study of Rai et al. (2009), they utilized a math learning environment with game-like elements to examine the effects on pupils' learning and engagement through controlled experiments. Based on the results of the study, 252 pupils were reported more satisfied with a more game-like tutor. Besides that, this showed that there were significantly higher levels of pupil's engagement as the game-like tutor have improved their learning as shown in the results between the pre-test and the post-test. Hence, the study concluded that the use of digital game-based learning can enhance pupils' engagement and make learning more enjoyable. Relevant study (Mitchell and Savill-Smith, 2004; Little, 2015) discussed about how digital game-based learning contributes to high levels of pupils' engagement with games based on several elements as below:

- *Fun*, which consist of enjoyment and pleasure
- *Play*, which consist of passionate and intense involvement;
- *Rules*, which provided structure;
- *Goals*, which provided motivation;
- *Learning outcomes and feedback*, which contributed to learning;
- *Adaptive elements*, which contributed to flow;
- *Winning*, which enhanced ego gratification;
- *Conflict and challenge*, which encourage engagement;
- *Problem solving*, which encouraged creativity
- *Interaction*, which provided social gratification; and
- *A story*, which engaged an emotional response.

Mitchell and Savill-Smith (2004) also noted that digital game-based learning can help pupils improve enhancement and retention of prior knowledge, develop the social and cognitive skills through interaction and solve problems in a game. Thus, digital game-based learning was effective as a learning tool for teachers and pupils in learning Mathematics as it promotes motivation and supports students' engagement in a game towards learning.

2.8 Technology in Learning Fraction

Technology in recent decades have caused changes across all dimensions of human coexistence in the way of how people interact with one another, work, shop and present themselves to society (Vecchia et al, 2015). Due to such changes, it had affected formal education, helping educators and researchers to understand the potential of digital technologies and use them to enhance the teaching and learning of Mathematics as a whole in the educational processes. Besides that, the advancement and popularity of the computer and multimedia technologies also offer opportunities for educators to design and conduct more meaningful learning activities in technology-enhanced learning settings (Hung, Huang & Hwang, 2014). There are various types of technological software that supported the learning such as Geogebra, Geometer Sketch Pad (GSP), Scratch, Logo and so on. There are several past researches that have proven that such technological software can be used effectively in Mathematic as a subject, especially in the topic of Fraction.

Besides that, the studies also reported positive results after conducting and using the technological software for learning fraction concept and knowledge. For example, Kafai, Franke, Ching & Shin (1998) had investigated a class of four fifth-grade students used programming computer games, Logo to teach Fraction to younger students. During the construction of the activity using Logo, students were able to build their understanding of operations of Fraction. Most importantly, they were able to make connections between the fraction concept and knowledge to every object they built by using the Logo programming software. The results of the study also showed the students significantly increased their understanding of the fraction concept after using the digital game-based programme; Logo. Thus, integrating technological software in learning mathematics offered opportunities for teachers and students to think about the learning context more mathematically and creatively. Teachers who used technology in mathematics were able to engage ongoing reflections about the teaching and learning of Fraction, enhance pupils' learning and also create a powerful game learning environment for students in classroom.

In recent years, Thambi and Leong (2013) had conducted a quasi-experiment research design to compare the achievement of two groups of primary Year Four pupils in learning Fraction using Geogebra. The reason for using Geogebra in their study is because it is a mathematical software tool that is appropriate for educational purposes and it also can be used for a variety of mathematical content topics (not only Fraction), allowing teachers and pupils to explore the mathematical concept. The results showed that the pupils in the experimental group performed better using Geogebra than the control group used the traditional learning method. Through the overall data analysis, it showed that the experimental group obtained a post-test mean score of 10.92 while the control group obtained a post-test mean score of 6.92. This result indicated that the pupils in the experimental group performed better in the post-test compared to the control group. Therefore, the technological software tool, Geogebra had been proven that it can be used to enhance pupils' visualization and understanding of fraction concept for both teachers and pupils.

2.9 Digital Game-Based Learning in Fraction

In the study of Brown, Shopland, Battersby, Tully and Richardson (2009) had done an experimental study to investigate the effectiveness of using digital game-based learning in mathematics, especially in Fraction. The respondents of the study were a group of pupils with intellectual disability (ID). Through this experimental study, they compared the experimental and control group which consist of 16 pupils with intellectual disabilities (ID) and were randomly assigned into two groups. Eight pupils were grouped in the experimental group and played the intervention games which were related to the topic of Fraction, while the other eight pupils were grouped in the control group that taught them how to play the game. The game, Cheese Factory, allow pupils to play according to their abilities and adapt to the difficulties of each game level at their own abilities. The pre-test and post-test were recorded to investigate the effectiveness of digital games in mastering fraction skills between these two different groups of students. The results of this study had shown that pupils in the experimental group improved in understanding fraction concepts and perform better fraction skills after the intervention, while other pupils in the control group did not make any improvement except for one student in the group.

Besides that, the research study of Riconscente (2013) had used an experimental repeated measures crossover design to investigate the effectiveness of Motion Math: Fraction to improve the fraction skills and attitudes of pupils without disabilities. A group of pupils of grade fourth were randomly assigned to experimental group or control group. The experimental group received the intervention in the first week, while the control group received the intervention in the second week. Pupils were tested with a pre-test before intervention, mid-test and a post-test after the intervention. Total of 122 pupils were participated in this study but due to incomplete data, researcher decided to drop out 20 pupils during the data analysis. The end result of this study had showed that pupils' fraction skills scores improved an average of over 15 % after playing the fraction game for 20 minutes daily over a 5-day period in school. It also showed a significant increase compared to control group. In addition, the results for fraction self-efficacy and interest were highly increased after playing the games. It shows a strong connection documented in the research literature between pupils's attitudes and learning result. Risconscrete (2013) also found out that the design of game app enables pupils to experience a sense of confidence in fraction and be rewarded for success each time they answer the question correctly. Therefore, this study of Riconscente (2013) had proven that the effectiveness of digital game app like Motion Math: Fraction had successfully integrated learning and entertainment, significantly improved pupils' fraction skills and positive changes in attitudes towards learning fraction.

Similarly, the study of Simsek (2016) also investigated that the effectiveness of using digital game-based apps as learning tools for students with Mathematics Learning Disabilities (MLD) to increase fraction knowledge and skills. There are four pupils who are from different grades and age groups from a public charter school in the Southeast part of US who participated in this study. The digital game app used in this study is fraction game *Motion Math*, which is also similar with the study of Riconscente (2013). However, the focus of the researcher in this study is to investigate on how pupils with Mathematics Learning Disabilities (MLD) used the digital game app in learning fraction skills. In the first two weeks, pupils received the intervention by playing the *Motion Math: Fraction* apps for 20 minutes per day. Pupils were tested for the next following two weeks to investigate if the pupils maintained the level of fraction skills they stopped engaging in the app. The result at the end of intervention showed that pupils with MLD had significantly improved their fraction skills after the intervention by playing the *Motion Math: Fraction* app for 20 minutes daily with little or no guidance from teacher. The achievement gap between pupils with MLD and without disabilities has steadily increased over time. The study also proved that the digital game app was effective in improving fraction skills for four students with MLD makes significant impact to engage mathematical tasks without requiring much teacher guidance. For example, the apps provided many response opportunities with feedback for pupils with MLD who need the feedback to improve the fraction skills. Furthermore, Simsek also pointed out that gaining positive improvement towards playing the app was connected with MLD's pupils spending more time to engage in the learning content in order to increase their opportunity to provide feedback and also increase the level of proficiency and knowledge at their own pace.

2.10 Zapzapmath app

Zapzapmathis an educational mobile app that had been designed to help primary school pupils from Kindergarten to Grade 6 pupils to learn math in a meaningful, engaging and effective way. This Zapzapmath app covers a comprehensive range of mathematical topics with a systematic structure that includes more than 10 topics of mathematics such as addition, subtraction, fraction, ratios, multiplication, geometry, coordinates, measurement, angles, time and so on. In term of learning, Zapzapmath app has covered over 180 math lessons to practice the mathematics skills, with a fully developed comprehensive curriculum that is aligned with international math curriculum, including the Common Core State Standard (US) (Zapzapmath, 2018). Besides that, the Zapzapmath game has been created to encourage and enhance pupils' critical thinking skills and incorporate the higher order thinking skills (HOTS) in the games itself with the aim of educating the pupils through creation, evaluation and analysis math games and puzzles based on Bloom's Taxanomy (Zapzapmath, 2018).

The Zapzapmath app is rich in content and features. It is a fast-paced, fun and interactive math game with hundreds of games for pupils to practice new math topics. Each math topic is divided into four levels areas such as Training, Accuracy, Speed and Mission. Pupils play the games from the simplest to the more complex levels and train their critical thinking, logic and problem-solving skills. The game app also provides gameplay narration for example, the math problems are read aloud to players for better understanding. It also provides hints to pupils while they are trying to solve a math problem. In additional, the games app also benefits parents and teachers as well. Parents and teachers are allowed to track their kids or pupils' individual performance online via the Web dashboard where they could see the Performance Analytic and Virtual Report Cards. Therefore, the features of Zapzapmath apps brings fun for pupils to engage in learning mathematics knowledge. Most importantly, it allowed parents, teachers and pupils to interact in an effective digital game-based learning environment.

In this study, researcher only focused on the topic of fraction when using the Zapzapmath app. The focus of the topic of fraction in these games are (a) knowing fraction, (b) equivalent fraction, (c) comparing fraction, (d) partitioning fraction (e) addition of fraction and (f) subtraction of fraction. The reason of selecting these subtopics is because the game apps itself had only designed these subtopics while the subtopics about multiplication and division of fraction are still under construction. Therefore, researcher would focus the subtopics that are available in the game app itself to investigate the effectiveness of using Zapzapmath app as a digital game-based learning tools to enhance primary Year Four pupils' achievement in Fraction.

When opening the Zapzapmath app, pupils have to choose an Avatar and name them from the scrolling list of two random names. Once they have chosen the character and the name, it is permanent. Next, the game set-up has a total of 9 galaxies for pupils to have the fun at all sorts of space stops. Each level within a planet consists of 5 progressive mini challenges. When pupils are able to complete a mini challenge, they will be awarded a star. The total collection of stars will accumulate award points. Pupils can use the accumulated award points to purchase and upgrade their spaceship in the game app. The spaceship has four levels. Pupils can customize the design of each levels. Therefore, pupils need to accumulate enough points to be able to use for spaceship decoration. The only way to earn more points is by playing the game continuously. Once a level is completed, pupils can continue on that planet's mission or the next planet's challenges. Thus, the rewarding system in Zapzapmath app had shown that the reinforcement is presented quickly and it engaged pupils to move forward and continue to play the next challenges.

The co-founder of this digital game-based math learning system (Zapzapmath app) is John Ng, a Singaporean based-math teacher, who found out that there is a learning gap between education and technology (Zapzapmath, 2018). He then builds up Zapzapmath with a team of experienced developers and educators to bring a gamified way of math learning in education. This game app had been piloted in 130 schools and counting. For now, the Zapzapmath's free download trial version can be found in the Google Play Store that comes with a range of 20 math games from Kindergarten to Grade 6. However, if pupils enjoy the free trial version, they can purchase the full range of content by grade on a yearly subscription basis. In this study, the researcher had asked the permission from Zapzapmath's company through e-mail in order to investigate the effectiveness of using the digital game-based learning as learning tool in learning fraction skills. As the company had approved the permission through replying an e-mail, the researcher had received the full version of the game that covers the full content by grade (see Appendix A). Therefore, Zapzapmath subscription gives each pupils access to all the games in their respective grades.

2.11 Summary

In summary, chapter II contained a review of literature associated with the Cognitive Information Processing Theory and Gagne's Conditional Theory. It had discussed how both theories were applied when using the Zapzapmath app in this study. Then, a brief discussion about the conceptual framework of digital game-based learning was presented in this study. This was followed by an overview of fraction skills or knowledge and problems encountered by students in learning fraction. Furthermore, there was a summary of the research on digital game-based learning, with a focus on the benefits of using digital game-based learning in Mathematics. Besides that, a literature review about other technologies that had been used in learning fraction and digital game-based learning in fraction achievement were also discussed in this chapter. A short and brief discussion about the Zapzapmath app as digital game-based learning tool was also clearly explained in this chapter.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter is about the methodology of research. In the first two sections, this chapter will present the research design, population and samples, and sampling techniques. The procedures of data collection are explained in detail with the flow of study presented in a diagram. Six lessons of instructional activities were designed to guide pupils in the experimental group. In the next section, samples of using Zapzapmath app are shown in the Instructional Activities. The instrument used for this study was Fraction Achievement Test which was adapted and modified from the National Assessment of Educational Progress (NAEP). A pilot study was done prior to this actual study is described in this chapter. In the following section, validity and reliability of instruments have been verified and explained including the data analysis method. A summary of this chapter is included in the last section.

3.2 Research Design

Quantitative research is used when the researcher is trying to quantify a problem by generating numerical data that can be counted into useable statistics (Creswell, 2013). Quantitative data is more structured statistically. It provides support when the researcher needs to draw general results form a larger sample population. Therefore, quantitative research is suited for this study because it helps the researcher to explain how one variable affects another, creating purposive statements, research questions and hypotheses that are specific, narrow, measurable and observable. In a quantitative research, numerical data is collected from a large number of respondents using appropriate instruments. Most importantly, the entire study of using quantitative research do not bring any biases or personal opinions into the study – unbiased approach. Quantitative research had clearly shown that it uses proven instruments to measure variables and it employs multiple statistical procedures to build objectivity into the study.

Unlike the qualitative research, it is used when the researcher is concerned with understanding human behaviour, thinking and motivation (Creswell, 2014). The reason of not choosing a qualitative research in this study is because of the method of qualitative data collects information that seeks to describe a topic in detailed rather than measuring it. Qualitative data is less structured and collects data based on a small number of individuals so that the researcher can focus more on obtaining participants' views and opinions. While the qualitative research brings depth of understanding to research questions, it also makes the results harder to analyse. This is because the entire study of qualitative research analyses participants' thinking, opinions, beliefs and experiences would cause bias when reporting the results in the study. Therefore, the qualitative research method is not suitable to be used in this study.

This study employed a quasi-experimental non-equivalent group pre-test and post-test design. Based on the definition provided by Creswell (2014), the researcher had both experimental group and control group where the participants were not randomly assigned in this quasi-experimental design. Thyer (2012) had described that the term control group and experimental group bring different meanings. A control group is one that does not receive any kind of formal treatment at all, while the term experimental group usually refers to those participants who received the actual treatment under formal investigation.

In this study, the researcher used quasi-experimental design to make comparisons between control group and experimental group but not focused on discovering the behaviour or attitude changes and gender that were involved in this study. As Goba, Balfour and Nkambule (2011) has supported that use of pre-test and post-test to measure the possibility of a strong correlation between variables. The quasi-experimental study is done by subjecting the experimental group to treatment or intervention while keeping a control group. The researcher can conduct a pre-test and a post-test to both experimental group and control group. A pre-test would be used to measure some attributes and characteristics that are assessed before they receive intervention (Thyer, 2012). By comparing with a post-test, it is used to measure attributes and characteristics that are assessed after the intervention. In this study, both pre and post-test would be used to assess pupils' achievement on learning fraction after using the Zapzapmath app. According to Creswell (2013), a pre-test and post-test comparison of pupils' achievement would provide an accurate data. Firstly, both groups will be assigned to do a pre-test at the beginning of the study. The difference between the two groups is, after the pre-test, the experimental groups would receive the intervention with using Zapzapmath app whereas the control group would learn fraction using the traditional approach. Finally, both groups would do the post-test at the end of the study to measure their achievement in fraction and its improvement.

By comparing with other quantitative research design such as correlational design, this study is not suited to use the correlational design because it only studies a single group of individuals with two or more variables or two sets of data in a study unlike the quasi-experimental design that focuses on two or more groups. Besides that, correlational design provides an opportunity for the researcher to predict the scores and explain the relationship among variables (Creswell, 2014). The researcher uses correlation statistics to describe and measure the relationship between two or more scores for each person in an experiment. However, in this study, the researcher needs to investigate the significance of the effectiveness of using digital game-based application in enhancing pupils' fraction achievement between a control group and a treatment group. A quasi-experimental design is suitable to be used in this study because both the control and treatment groups' respondents in this study were not randomly assigned. The respondents were not randomly assigned as the researcher has selected convenience sampling for this study. It is easier and more accessible for the researcher to take an entire class as a treatment or control group instead of selecting respondents individually and randomly. The researcher also used respondents with similar traits for both the control and treatment groups. The focus of this study is on the fraction skills of both groups. By using the non-equivalent pre-test and post-test design, the researcher can determine the achievement of pupils in fraction within the intervention period. Quantitative data would be sufficient in determining the pupils' achievement in fraction from both groups. In this study, the quantitative analysis will be used as the research method is to identify pupils' achievement in fraction.

Diagram 1.0 shows the research design of quasi-experimental design that will be conducted as below:

Diagram 1.0

Research Design

Experimental group	O1	X1	O2
Control group	O1	X2	O2

O1 represents the pre-test

O2 represents the post-test

X1 represents the students learning fraction using *Zapzapmath: Fraction app*

X2 represents the students learning fraction using traditional method

The reason for selecting quasi-experimental design in this study is the analysis of pupils' achievement using Zapzapmath app can be done between groups which are with or without intervention for the experiment group only. For this research, only the experiment group receives the intervention with using Zapzapmath app in enhancing their achievement in fraction. Another reason of selecting quasi-experimental design is to test the hypotheses in the research. There are three hypotheses were formed based on the research questions. Quasi-experimental design is chosen rather than other experimental designs because it let to have some rival hypotheses since there is less control in it. Besides that, one of the criteria of choosing a treatment group and a control group in quasi-experimental design is that the groups must match each other. Therefore, there should not be much difference between them and lastly the results are not jeopardized (Goba, Balfour and Nkambule, 2011).

The strength of using quasi-experiment is can help researcher spend less time and reduce resources needed as compared to a true experimental study. The reason of not choosing the true experiment design in this research is because the participants or sample in true experiment are randomly assigned whereas the participants in the quasi-experiment design are not randomly chosen. Grabbe (2015) described that a true experimental design is based on random assignment of participants to an experimental group and at least one control and or comparison group. The strength of a true experimental design is that the participants are randomly assigned to treatment groups. However, the quasi-experimental design does not include a random assignment in the study (Creswell, 2014).

In this study, the participants were Year Four pupils from two classes at the same school. Both classes have similar scores on a standardized math test. Both classes were not streamed and the researcher used coin-tossed method to assign one of the classes as the experimental group and the other class as a control group. The control group consisted 28 pupils. Pupils in the control group were taught using traditional approaches in learning fraction for six weeks. On the other hand, the experimental group also consisted 28 pupils. They used Zapzapmath app to improve fraction and underwent the instructional modules for six weeks. The focus of this study is to find out the difference in learning fraction between the pupils who learned fraction through digital game based learning with using Zapzapmath app and those who learned fraction through the traditional approach.

3.3 POPULATION AND SAMPLE

According to Webster (1985), a sample is a finite part of a statistical population whose properties are studied to gain information of the whole. Sample can be defined as a set of respondents selected from a larger population for the purpose of the study (Martinez-Mesa, Gonzalez-Chica, Duquia, Bonamigo & Bastos, 2016). The population is a group of people, individuals, objects or items from which the sample are taken for the measurement (Creswell, 2013). Sampling is defined as the process used in statistical analysis in which a pre-determined number of observations will be taken from a larger population. According to Mugo (2002), sampling is the act, process or technique of selecting a suitable sample or a representative part of a population for the purpose of determining parameters or characteristics of the whole population. Sampling plays an important role in the research because the selection of unsuitable sampling will reduce the validity and reliability of the research and also increase sampling and measurement errors.

In order to draw conclusions about populations from a sample, the purpose of sampling is to use inferential statistics which enable the researcher to determine a population characteristic by directly observing only a portion of the population (Mugo, 2002). Method of sampling depends on the type of the research. There are two types of sampling such as probability sampling and non-probability sampling. Based on the research of Henry (1990), probability sampling defined as having distinguishing characteristics that each unit in the population has a known, nonzero chance of being selected in sample. It is further explained that as every participant has an equal probability of being selected from the population. In non-probability sampling, randomization is not important in selecting a sample from the population of interest

(Etikan, Musa, & Alkassim, 2016). However, it is a sampling technique where the samples are collected in a process that did not give all the participants in the population equal chances of being included.

In this study, non-probability sampling technique is applicable because it is cheaper than probability sampling and can be implemented more quickly to save time. There are two types of non-probability sampling known as convenience sampling and purposive sampling. When the participants are chosen because they are closer approximated to the researcher and easier for the researcher to access and collect data, it is known as convenience sampling. But for purposive sampling, the participants must be suited to the objective of the study and the researcher has to decide what needs to be known and find the people who are willing to participate and provide useful information by the value of knowledge and experience. According to Zhi (2014), the convenience sampling technique is the most frequently applied sampling in quantitative studies while the purposive sampling technique is typically applied in qualitative studies.

Since this is a quantitative design, convenience sampling is used to select the participants from a large group of population. Besides that, the researcher has decided to use convenience sampling because the participants meet certain criteria such as easy accessibility, availability at a given time and the willingness to participate for the purpose of this study. This study employs convenience sampling which is emphasized on generalizability to ensure the knowledge gained is representative of the population from which the sample was taken (Etikan et al., 2016). Convenience sampling helps researcher selects participants that are more readily accessible unlike the purposive sampling, participants are selected based on study purpose with the expectation that each participant will provide useful information like experience, opinions or reflective manners. The sample size of this study is a total of 56 pupils that increases the statistical power of the convenience sampling whereas in purposive sampling, sample size is determined by small amount of individuals and not by statistical power analysis (Etikan et al., 2016).

However, there are few disadvantages in the convenience sampling. Firstly, the study can be biased. Secondly, the generalization is more plausible if the data is presented to show that the sample is representative of the intended population on at least some relevant variables (Jack et al., 2015). The disadvantages were tackled because common problems are notified among Chinese primary schools. On that purpose, Chinese primary school pupils were chosen. The pupils represent other Chinese primary school who are in Year Four with similar characteristics.

The samples are selected through convenience sampling method. The reason the researcher choose the convenience sampling method is because the researcher is currently working at one of the Chinese primary school which is located in the district of Bangsar Pudu where the research samples are accessible to researcher in the same school. Besides that, another reason is because the participants are willing to participate in this study and available after school hours. Therefore, the researcher can conduct the research after school hours; within one hour for each lesson in six weeks.

Besides that, the school has sufficient facilities for the pupils' usage. The school has a computer lab with 30 personal computers. Therefore, each of the pupil would use the computer individually during the intervention using the Zapzapmath app. Besides that, the computer lab also facilitates a smart board, speakers and a Liquid-Crystal Display (LCD) Projector. It is easy for the researcher to give instructions and display each of the instructions before the lesson activities begin during the intervention. Additionally, pupils are able to understand the instructions and explanations when the game is displayed on the screen clearly. Therefore, pupils would be able to know how to navigate the Zapzapmath app in learning fraction.

The research consists of 56 Year Four pupils as respondents from a selected school. Majority of the pupils are Chinese and the rest are Malays and Indians. The selected respondents a group pupils with mixed abilities. They were selected to provide a rich data, in which the pupils do not have prior knowledge of the Year Four Mathematics syllabus, especially in the topic of fraction. The 56 pupils were assigned into two different groups which includes the experimental group and control group. 12 males and 16 females were assigned to the experimental group whereas 17 males and 11 females in the control group.

All of them were selected to provide rich data since they had not been exposed to use any technological apps like Zapzapmath app before in classroom. When 56 pupils participate in this study, it is considered as a large sample size. As Goba, Balfour and Nkambule (2011) has reported that when there are 30 respondents and above, sample size is considered statistical. They further described that it would become a strength of the experimental study as it has the ability to make meaningful utilization of large quantities of data. In addition, the size of the large sample plays an important role in the producing credible results. The results from large data sets will be more trustworthy because the measurement error will be minimized.

3.4 DATA COLLECTION

A Fraction Achievement Test was administered to the pupils in both experimental and control groups to determine their initial knowledge about fraction. Three days after marking the pre-Fraction Achievement Test, the experimental group received intervention for six weeks with using the Zapzapmath app. There were two qualified Mathematics teachers who were involved in this research to conduct the lessons for the students. The teacher who taught the control group has experience in teaching Mathematics for 15 years in Chinese primary schools. Besides that, another teacher who taught the experimental group also has experience in teaching Mathematics for 13 years in Chinese primary schools. The Mathematics teacher introduced the use of Zapzapmath app to pupils in the experimental group with the smart board. The researcher also demonstrated the way to log into the account. Each pupil received their own username and password to log into the app. Next, pupils were guided to select their favourite avatar before the game begins. Once that is done, pupils explored the fraction game beginning from Level 1 and completed the tasks provided within 30 minutes in the computer lab. Teacher walked around to provide guidance if necessary.

The research procedures were illustrated and shown in Table 3.1. The lesson was conducted 60 minutes per day after school ends. Each subtopic of fraction has five levels with each level more difficult that the one before. The game itself also prepares a pre-test for pupils to test their initial level of fraction in the game. After the pre-test is done, pupils would proceed to play the game at level 1. Pupils have to answer all the questions at that level before they can proceed to more advanced levels in the game. The pupils' achievements in the game were recorded and shown on the dashboard of their own account. It is also more convenient and easier for the researcher to collect data of the pupils in the experimental group from the game app. The researcher can track the pupil's scores from the website anytime and anywhere.

Table 3.1

Research Procedures

Research Procedures	
Experimental Group	Control Group
1.Pre-test 2.Introduction of using Zapzapmath app 3.Using game principle and instruction with using Zapzapmath app Lesson 1: Part-Whole Fraction Lesson 2: Equivalent Fraction Lesson 3: Partitioning Fraction Lesson 4: Comparing fraction Lesson 5: Addition of Fraction Lesson 6: Subtraction of Fraction 4. Post-test	1. Pre-test 2. Instruction using traditional approach (Teaching with using textbook and worksheet only) Lesson 1: Part-Whole Fraction Lesson 2: Equivalent Fraction Lesson 3: Partitioning Fraction Lesson 4: Comparing fraction Lesson 5: Addition of Fraction Lesson 6: Subtraction of Fraction 3. Post-test

Beginning from week 2 until week six, the pupils in the experimental group were guided to use Zapzapmath app in learning fraction. However, the pupils in the control groups were given the traditional approach of learning fraction. The instructions given to the pupils in the experimental group is based on the Information Processing theory and Gagne's Nine events of Instruction to guide pupils to achieve better performance in fraction. Besides that, fast learners in the experimental groups can proceed at a faster learning pace without waiting for slower learners in the group. Since pupils played the game individually using the personal computer in the school, slow learners can finish the game at a slower pace without time limit. During the whole process of learning, pupils were encouraged to participate actively in the game and answer all the questions. Mathematics teacher plays the role as a facilitator by giving instructions from the instructional module.

For pupils in the control group, they receive different instructions from the pupils in the experimental group as they were not using any technological tools like the Zapzapmath app to learn fraction. Pupils in the control group learn fraction through textbooks, activity books and exercises that were designed by the Zapzapmath app. The researcher adapted the questions from the app and transformed it into an inanimate exercise so that pupils in the control group will be doing the same questions as the pupils in the experimental group. Besides that, another Mathematics teacher used the chalk and talk method to teach fraction based on the guidelines in the textbook. Pupils learned fraction and received instructions from the researcher passively in the control group. The samples of lesson plans and worksheets provided for the pupils in the control group were attached in Appendix B. After learning fraction in the control group, the teacher would give pupils exercises as “drill and practice” to determine the level of pupils in mastering fraction. After the pupils answer the exercises, teacher would lead pupils to a discussion of each question from the exercises.

After the six weeks of the intervention period, the post-test was given to pupils in both experimental and control groups to evaluate their levels in learning fraction. During the evaluation process, pupils in the experimental group were not allowed to use Zapzapmath app. Therefore, both groups of pupils were given the same condition and environment during the post-test. The flow of research procedures is shown in Figure 3.1.

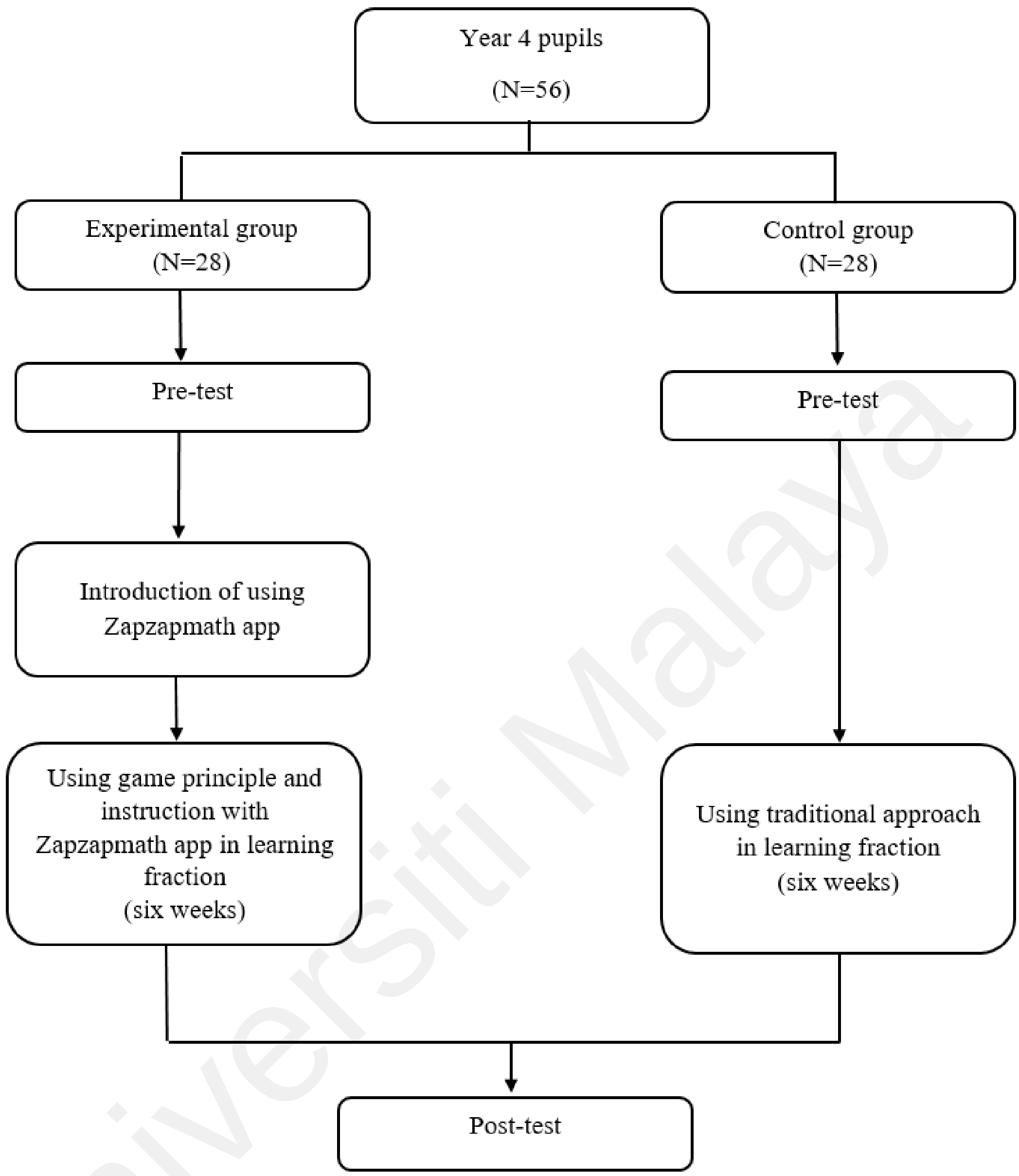

Figure 3.1. Flow of the stages in the quasi-experimental research procedures

3.5 INSTRUCTIONAL ACTIVITIES

There are a total of six instructional activities in the Zapzapmath app for pupils to visualize fraction and identify the concept of fraction. The activities include Lesson 1 (Part-Whole fraction), Lesson 2 (Equivalent of fraction), Lesson 3 (Partitioning fraction), Lesson 4 (Comparing fraction), Lesson 5 (Addition of fraction), Lesson 6 (Subtraction of fraction). An Instructional Module for the experimental group was designed based on Information Processing Theory and the Gagne's nine event of instructions that includes content, goal, feature, interaction and application is attached in Appendix C. The content of fraction mainly focuses on six fraction lessons, which are (a) identify part-whole fraction, (b) identify equivalent of fraction, (c) identify partitioning fraction (d) comparing fraction, (e) identify the fraction addition and (f) identify the fraction subtraction. The purpose of designing this instructional module is to guide pupils in the learning of fraction.

At first, two intact groups were respectively chosen from the Year 4 group to sit for the pre-test. After the pre-test, the experimental group had interventions for six weeks using Zapzapmath applications. The interventions for the experimental group was planned for 6 lessons as shown in Table 3.2. The detailed lesson plan for the experimental group is attached in Appendix D. The interventions were developed based on the Information Processing Theory and the Gagne's nine event of instructions. According to Eggen and Kauchack (2007), the theory requires pupils to retrieve and reconstruct their existing knowledge which helps them to continue developing new knowledge and skills through playing games (Zapzapmath application). When the pupils had unlocked the achievements to each levels of game-play, pupils are able to relate their new knowledge to the knowledge already stored in their memory (Gagne et al., 2005). Thus, based on the criteria suggested in the theory and instructions, the interventions planned are integrated with theory and instruction to help pupils remember easily and learn new knowledge and skills more effectively.

For the first week, both the experimental group and control group pupils were given a pre-test. The second week, the pupils in the experimental group were introduced to Zapzapmath application by the teacher. Each lesson was carried out for one and half hour. The following week, the teacher started the intervention with the experimental group with the Zapzapmath application. After learning the concept of that lesson, pupils used *Zapzapmath* app to explore fraction through playing the games. After spending 20 minutes of playing the game, pupils attempted the exercises and solved the problem that were given in the module. Pupils were given 20 minutes to solve the problems and discuss with their peers. At this end of the lesson, pupils were required to present their idea in front of the class and the discussion of answers were done after the presentation.

Meanwhile, the control group was taught using the traditional approach. The detailed lesson plans are shown in Appendix B. When the interventions were fully completed, both groups were given a post-test the following week.

Table 3.2

Lesson Planning for Interventions

The Content of Fraction	The Learning Objectives of Lessons
Lesson 1 : **Part-Whole fraction**	At the end of this lesson, pupils will be able to (a) Identify, read and write part-whole fraction. (b) Write a fraction to describe what part of a region is shaded. (c) Name the numerator and denominator in a fraction.
Lesson 2 : **Equivalent of fraction**	At the end of this lesson, pupils will be able to (a) Understand the meaning of "equivalent" of a fraction are two or more ways of describing the same amount by using different size fractional parts. (b)Calculate equivalent fraction with multiplication method when given two corresponding numbers.
Lesson 3 : **Partitioning fraction**	At the end of this lesson, pupils will be able to (a) Understand the meaning of partition of a fraction. (b) Partition objects into equal parts and name the parts.
Lesson 4 : **Comparing fraction**	At the end of this lesson, pupils will be able to (a) Compare fraction by reasoning about their size. (b) Find common denominator by changing both fraction to equivalent fraction. (c)Record the results of comparisons with symbols ›, = or ‹ and justify the conclusion.
Lesson 5 : **Addition of fraction**	At the end of this lesson, pupils will be able to (a) Add fraction with LIKE denominator. (b) Add fraction with UNLIKE denominator. (c) Simplify fraction to mixed numbers.
Lesson 6 : **Subtraction of fraction**	At the end of this lesson, pupils will be able to (a) Subtract fraction with LIKE denominator. (b) Subtract fraction with UNLIKE denominator. (c) Simplify fraction to mixed numbers.

3.6 INSTRUMENTS

3.6.1 PRE-TEST AND POST-TEST

Achievement tests are widely used to estimate what students know and can do in specific areas (Chair, Embretson, Fernell, Fristedt, Loveless, Schmid, Stotsky, Arispe & Kelly, 2016). In this study, the researcher used the Fraction Achievement Test as pre-test and post-test to find out pupils' scores in fraction (See Appendix E). Besides that, this Fraction Achievement Test's pilot study had been conducted by the researcher and the reliability and validity were addressed in this study as well. The pre and post Fraction Achievement Test was adapted from National Assessment of Educational Progress (National Assessment of Educational Progress, 2014). Questions were taken from different resources: a total of 20 items that have been released between 1990 until 2013 from the National Assessment of Educational Progress (NAEP). The questions of fraction were adapted in different forms, such as pictorial representations or number lines.

The rationale for the selection of Fraction Achievement Test is that the instrument aims at measuring the variable which is mathematics achievement of the pupils in fraction, in which the researcher intended to measure in this study. In addition, this instrument's content and objectives are appropriate for this study since it is closely related to the topic of fraction and it was distributed according to the subtopic of fraction. A total of 20 multiple choice questions were used in the pre-test and post-test. The questions in the Fraction Achievement Test are related to the objectives that the researcher wanted to investigate in this study. Moreover, this Fraction Achievement test is used in quasi-experimental studies, which investigates the effect of using digital game-based learning and educational apps on pupils' fraction achievement. Therefore, this instrument was deemed appropriate for this study.

The scoring rubric of Fraction Achievement Test was adapted according to the rubric which was prepared by the National Assessment of Educational Progress, NAEP (NAEP Technical Documentation, 2017) (See Appendix G). After referring to the Report of a task group on Assessment by Chair et. al (2016) and Simsek's (2016) scoring criteria, the researcher made an assumption that pupils are considered advanced learners if and only if they can score sixteen out of twenty items in the Fraction Achievement Test. According to Simsek (2016), questions were scored 0 (incorrect) and 1 (correct). The answers of the Fraction Achievement Test were prepared by the National Assessment of Educational Progress, NAEP (U.S. Department of Education, 2014) as shown in Appendix F.

Then, this instrument was used as a pre-test one week before the study begins to determine whether the pupils in the experimental group and control group differed from each other in terms of academic achievement. Also, the Fraction Achievement Test was implemented as a post-test to both groups one week after the intervention or treatment was completed. The pre and post Fraction Achievement Test were used to assess pupils in identifying, comparing fraction and solving word problems including fraction operations. The pupils need to understand the real-world problems that involved operations of fraction in their everyday life. The distribution of items in the pre and post Fraction Achievement Test was illustrated in Table 3.3.

Table 3.3

Distribution of Items in the Pre and Post Fraction Achievement Test

Question Number	Concept	Question type
1	Part-Whole	Identify picture model of fraction
2	Part-Whole	Identify picture model of fraction
3	Part-Whole	Identify picture model of fraction
4	Part-Whole	Identifying a fraction representing the shaded part of a region
5	Part-Whole	Identifying a fraction representing the shaded part of a region
6	Comparing	Identify fraction closest to given value
7	Comparing	Comparing Unit Fraction
8	Comparing	Concluding the Fraction Model
9	Comparing	Concluding the Fraction Model
10	Equivalent	Identify pictorial representation of equivalent fraction
11	Equivalent	Identify pictorial representation of equivalent fraction
12	Ascending Order	List the fraction in ascending order
13	Partitioning	Identify the value of a point on a number line
14	Partitioning	Solve a story involving partition of fraction
15	Fraction Addition	Add up three fraction with like denominator
16	Fraction Addition	Solve a problem involving addition fraction
17	Fraction Addition	Solve a problem involving addition fraction
18	Fraction Subtraction	Subtract fraction with like denominator
19	Fraction Subtraction	Solve a problem involving subtraction fraction
20	Fraction Subtraction	Solve a problem involving subtraction fraction

In the first to fifth item, pupils need to identify picture models of fraction based on the diagram shown visually. Pupils have to identify what part of a region is shaded. Then, pupils need to select the correct numerator and denominator in a fraction based on the diagram. In the sixth to ninth item, pupils need to compare the fraction involving the identification of which fraction is closest to a given value, comparing unit fraction and concluding which statement is true based on both fraction models given.

In the tenth to eleventh item, questions were adapted to evaluate how pupils identify pictorial representations of equivalent fraction. Besides that, pupils need to list out the fraction in ascending order in the twelfth item. Next, pupils will identify the value of a point on a given number line and solve a word problem involving partition of a fraction in the thirteenth and fourteenth item. After that, pupils need to add up three fractions with like denominators in the fifteenth item. In the sixteenth to seventeenth item, pupils were asked to solve a word problem involving addition fraction. In the eighteenth item, pupils need to subtract fraction with like denominator. The word problems that involve subtraction fraction were shown. Pupils were asked to read carefully and solve the problem in the nineteenth and twentieth item.

3.7 VALIDITY

According to Smith and Fey (2000), validity is the quality of an instrument to yield truthful inferences about the trait it measures. Kadijevich (2005) also supported that validity is about the concerns of the research to which the conclusions are trustworthy, drawn from the collected data and match with the reality (internal validity) as well as the research to which the obtained findings are generalizable to a larger population (external validity). In this study, the types of relevant validity are content validity, internal validity and external validity.

The instrument for this study were adapted and it was necessary to test the items in terms of Item Difficulty Index and Item Discriminant Index. For item Discriminant Index and Item Difficulty Index, an ANATES test was done. ANATES is a program used to analyse reliability, discriminant index, difficulty index and correlation of each score of multiple choices questions and open ended-questions. For item difficulty and item discrimination of each item have been measured using the ANATES version 4.1.0 analysis. The results of analysis per each item are:

The indices of item difficulty level of each item are presented in Table 3.4. Test items were classified into three categories in terms of level of difficulty (Instructional Assessment Resources (IAR), 2011) as indicated in the Table 3.5.

Table 3.4

Item difficulty of comprehensive test items

Item No	Item Difficulty	Item No	Item Difficulty
1	0.842	11	0.854
2	0.788	12	0.626
3	0.806	13	0.738
4	0.740	14	0.544
5	0.726	15	0.766
6	0.680	16	0.484
7	0.256	17	0.388
8	0.204	18	0.896
9	0.168	19	0.606
10	0.386	20	0.148

Table 3.5

Classification of difficulty level

Value of Difficulty Index	Classification
0.00 – 0.30	Difficult
0.31 – 0.70	Moderate
0.71 – 1.00	Easy

Source: Instructional Assessment Resources (IAR, 2011)

The indices of item discrimination of each item are presented in Table 3.6. The items were classified accordingly to their discrimination index on Table 3.7. If the value of the discrimination power is negative, the item test should be rejected (Arikunto, 2012).

Table 3.6

Item discrimination of comprehensive test items

Item No	DP	Item No	DP
1	0.288	11	0.606
2	0.451	12	0.343
3	0.530	13	0.711
4	0.530	14	0.316
5	0.296	15	0.183
6	0.358	16	0.598
7	0.204	17	0.500
8	0.664	18	0.194
9	0.672	19	0.384
10	0.626	20	0.490

Table 3.7

The Classification of Discriminating Power (DP)

Discriminating Power (DP)	Interpretation
0.00 – 0.20	Poor
0.21 – 0.40	Satisfactory
0.41 – 0.70	Good
0.71 – 1.00	Excellent

Source: Ebel (1972) in Ovwigho (2013)

Difficulty index of this test is resulted from the analysis by ANATES version 4.1.0. Test items were classified into three categories in terms of level of difficulty as shown in the Table 3.5 such as easy, moderate and difficult. Based on the results, the item numbers which were classified as the easy level are numbers 1, 2, 3, 4, 5, 11, 13, 15 and 18. Item numbers which classified as moderate level are 6, 10, 12, 14, 16, 17 and 19 whereas classified as difficult are numbers 7, 8, 9 and 20. The total number which were classified as easy 9 items, moderate 7 items and difficult 4 items. Based on the results shown in Table 3.4, most of the item numbers that have item difficulty were categorized as “moderate”. There were 4 items which were categorized as “difficult”. From the analysis of the researcher, one of the reasons that influenced the difficulty index is the level of pupils’ understanding of the question and the information that was provided. For example, when the instrument was tested in the classroom, there were still pupils who were confused with the terms that were used in the questions and the information that was given in the test.

Besides that, the results of discrimination for the test was shown in Table 3.6. Item discrimination was used as a measure to discriminate between pupils in the top with that of the lower group who obtained the correct answer. A highly discriminating item indicates that the pupils who had high tests scores got the item correct whereas pupils who had lower test scores got the item incorrect (Zimmaro, 2004). From the results of the analysis, it was found that the number that was categorized as a poor item is number 18, satisfactory items are numbers 1, 5, 6, 7, 12, 14, 15, and 19, good items are numbers 2, 3, 4, 5, 8, 9, 10, 11 , 16, 17, 20 and an excellent item is number 13. Based on the results, the number of items that has good quality that differentiates between the high respondents and low respondents are 19 test items or 95% of the test items.

For the content validity, the items in the instrument of Fraction Achievement Test were adapted from the National Assessment of Educational Progress (National Assessment of Educational Progress, 2014). The National Assessment of Educational Progress (NAEP) mathematics assessment was used to measure pupils' understanding and knowledge in mathematics and pupils' ability to apply their knowledge in problem-solving. The items were collaboratively developed by a group of expert panels that involved mathematicians, math educators and an expert on state-based mathematic standards. After that, the items were reviewed by educators, parents and experts for feedback and revision. The complexity of the assessment can be classified into three categories such low complexity, moderate complexity and high complexity with the purpose to ensure the process meets the highest standards of reliability, validity and accuracy measurement.

Furthermore, the NAEP mathematics assessments for grade 4 and 8 were typically piloted two years before they were finalized. After constructing the items in the Fraction Achievement Test, the instrument was shown to experienced mathematic lecturers in University Malaya. According to the lecturers, the instruments fulfilled the content validity that the questions from Fraction Achievement Test can help in gathering information about pupils' improvement in the lessons of fraction according to Information Processing Theory and Gagne's Nine Event of Instruction. In addition, the items were congruent to the pupils' content domain which was focused on the topic of fraction.

Besides that, the content of the instructional module activities for the experimental group was also checked and validated by three experts. Firstly, a mathematics teacher who worked more than 15 years in primary school. He stated that the pictorial representations in Example 1 and 2 in topic of part-whole fraction were unclear. Secondly, he asked to make Problem 3 in the topic of part-whole fraction simpler. The examples and questions were corrected as he suggested. Then, the module was sent to Mathematics Leader of the Bangsar District in Kuala Lumpur. She was teaching Mathematics for more than 20 years in both primary and secondary school. She checked the notes and problems of each construct. She found that there was some missing symbols in the topic of comparing fraction in Example 1. Then, she corrected the sentence structure of Problem 1, 2 and 3 in the topic of comparing fraction. Furthermore, she said the overall notes and question in this module was clear. Finally, in ensuring the content validity, this module also sent to a lecturer of the Mathematics and Science Department from the Faculty of Education, University of Malaya, for checking. The vocabulary of Problem 1 in the topic of equivalent fraction was corrected based on the feedback from the lecturer.

In this study, the threat of mortality does not affect the internal validity as all the pupils have fully participated in both the experimental and control group (Creswell, 2013). It means that there were no pupils missing in both pre and post Fraction Achievement Test. Furthermore, pupils in both experimental and control groups received treatment or the traditional approach within the same duration. Therefore, the threat of maturation can be minimized (Creswell, 2013). As all the lessons were conducted within six weeks, each lesson is fixed as two hours per two days.

Subject characteristics threat can be minimized when the pupils are not randomly assigned to the experimental group and control group during administered pre-Fraction Achievement Test; before the study is conducted. The researcher was able to know the difference in fraction achievement among the pupils in both experimental group and control group which was significant at the initial level, which could help gather information to answer the first research question. Thus, the researcher assumed that the threat to the internal validity of this study was controlled.

Besides that, post-test was administered six weeks after the pre-test was given. The name and figures in both tests would be changed. Therefore, the pupils might not be able to recognize or recall the questions posed in the pre-test easily. Moreover, the testing threat towards the internal validity of this study can be minimized.

Internal validity refers to whether the effects observed in a study are due to the manipulation of the independent variable and no other factors. Internal validity can be improved by controlling extraneous variables, using standardized instructions, counter balancing and eliminating demand characteristics and investigator effects (Moutinho & Hutcheson, 2011). In this study, a pilot study was conducted to test the internal validity.

External validity refers to the extent to which the results of a study can be generalized from the specific sample to a larger group of subjects (Campbell and Stanley, 1963). The environment of the study is referred to the place of the research conducted where the culture of the school was not amended to suite the research. As the convenience sampling was used to select the school and pupils, the results of the study might not be generalized to represent the population of the study. Besides that, the study might be subjected to the threat of ecological validity that refers to the extent to which the results can be generalized from the set of environmental conditions created by the researcher to other environmental conditions such as settings and conditions. The pupils in the experimental group used ICT facilities to receive the intervention whereas the pupils in the control group received the instruction in a classroom setting. However, the number of pupils in both experimental and control groups, the seating arrangements, lighting in both locations are almost the same. Therefore, the threat can be minimized in this study.

3.8 RELIABILITY

According to Creswell (2014), the reliability of an instrument is the degree to which the instrument measures accurately and consistently of what it was intended to measure. The reliability of the pre-test and post-test in this study were established using the data from the pilot study via the test-retest method that involved 48 Year 4 pupils from a Chinese primary school in Kuala Lumpur.

The reliability of a research refers to the capability of the research in obtaining the same value when the measurements are repeated. This capability is called internal consistency reliability and it can be assessed by comparing the correlations values among selected methods. For the reliability of the instruments, a test-retest was done using SPSS version 22.00 and the Pearson correlation test results showed that the group of subjects (n=48), the correlation value for the test is 0.789. This means that the instruments were suitable in obtaining reliable data from other subjects who have the same characteristics as the respondents in this study.

In this method, the same test was given for the second time after a month (Mac and April 2019). Since the r value is bigger than 0.65, this instrument was reported to be suitable for obtaining reliable data from respondents in the same research location (Chan & Ismail, 2014).

3.9 PILOT STUDY

According to Goba, Balfour and Nkambule (2011), many experienced researchers emphasized the importance of pilot studies before the actual research is done. They further explained that the reason of doing pilot study is because a pilot study yields data concerning instrument deficiencies as well as suggestions for further improvements. Besides that, a pilot study was important to help improve any possible defects in text and test items. Thus, all the comments and suggestion from pupils were recorded to assist the actual data collection.

A pilot study was conducted on 48 Year 4 pupils from two intact mixed ability classrooms from a Chinese primary school in Kuala Lumpur. The reason for choosing Year 4 pupils is because most of them had learned the skills in the topic of Fraction. Twenty-four pupils were assigned to the experimental group and the remaining twenty-four pupils were assigned to the control group. The pre-test was piloted in the study for validation and reliability purposes and also to check on pupils' understanding of questions given. Before the pre-test was given, pupils were given instructions for 5 minutes. Then, pupils were given an hour to complete the Fraction Achievement Test which consists of 20 multiple choice items in the test.

After an hour, the paper was collected. Most of the pupils were able to complete the test in given time. Only a few adjustments were needed to be made based on pupils' comment on the paper. Firstly, the time for pre-test and post-test reduced 15 minutes as most of the pupils were able to finish the test within 30 minutes. For another 30 minutes, pupils had started complaining as the time allocated for the test was too long. Therefore, 45 minutes was the most suitable timing for pupils to answer all the questions after discussing with the supervisor.

3.10 DATA ANALYSIS

Quantitative data analysis was used to analyse the data obtained through the Fraction Achievement Test. After the pre-test was conducted, the researcher checked the pupils' responses and marked the answers based on the rubrics prepared. The items that were answered correctly by pupils were labelled as "1" while the items that were answered incorrectly were labelled as "0". The improvement in fraction achievement by pupils was determined based on the criterion as shown in Table 3.8. The same process will be taken for post-test. The scoring rubrics of the pre-test and post-test is attached in Appendix G.

After the marks for pre-test and post-test of each questions were collected, the total marks were keyed in Statistical Package for Social Sciences (SPSS) version 20.00. The data was analysed based on the research questions. Research Questions 1, 2 and 3 by using inferential analysis.

Research Question 1: To answer this research question, a paired-samples t-test was used to find out if there was any significant improvement between the pre-test and post-test of the control group Year Four pupils' fraction achievement.

A dependent t-test or paired-samples t-test was chosen for the first research question. This is because it fulfilled the assumptions. Firstly, it measured the pupils' scores using the same instrument or test-paper after some duration. Secondly, the dependent variable which is the pre-test and post-test are considered as interval scales. Thirdly, the two classes were randomly chosen from the population of Year 4 Chinese primary school. Lastly, the data was checked for normality using Shapiro-Wilks test because the samples were below 30. However, if the assumptions are violated, the non-parametric test of Wilcoxon signed-rank test will be used to analyse data.

Research Question 2: To answer research question 2, pair-sample T-test was used to find out if there was any significant improvement between the pre-test and post-test of the experimental group of Year Four pupils' fraction achievement.

According to Chua (2013), the paired-samples t-test is a statistical procedure used to determine whether the mean difference between two sets of observations is zero. He further explained that the paired-samples t-test is used when each subject in the sample is measured twice using the same test or apps before and after a period of time, then both the data are compared. It is used to analyse two sets of repeated-measure data. Through this method, the pupils in the experimental group before using the app was measured and the pre-test score was collected. When pupils in the experimental group had mastered the fraction knowledge using the game app, the same subject is measured again in order to obtain the post-test scores. Later, the pair-sample t-test was used to determine if there was any difference between the means of both sets of data obtained from the pre-test and post-test of pupils in the experimental group before and after using the Zapzapmath app. To conduct pair-sample t-test assumptions, normality was tested. The assumptions were required to conduct the pair-sample t-test. If the assumptions are violated, the non-parametric test of Wilcoxon signed-rank test will be used to analyse the data.

Research Question 3: To answer research question 3, the post-test scores in the experimental group and control group was analysed using covariance analysis (ANCOVA). As in the study of Yilmaz (2015), by applying ANCOVA to the data obtained from the pre-test and post-test, the difference between the groups' achievements were able to be determined. Similarly, the post-test was conducted in this study with using SPSS to find out if the mean of fraction achievement of the experimental group in the post-test was significantly greater than the control group.

The reason of using covariance analysis (ANCOVA) for answering the third research question was because it has met the assumption in this study (Creswell, 2014). Firstly, the sample size of this study contains more than 50 pupils which was enough to obtain an accurate result. Secondly, the research was conducted to explore if there was a statistical significant difference between two groups of data that included the experimental group and control group. Thirdly, the dependent variable in this study was the pre-test and post-test scores of pupils which was known as the interval scale. Therefore, ANCOVA was conducted to determine whether the mean of fraction achievement of the experimental group in the post-test was significantly greater than the control group, when controlling for the pre-test. If the assumption of normality in post-test is violated, then non-parametric test of Mann-Whitney U test will be used in the data analysis.

Table 3.8 shows the summary of the data analysis method of each research questions from 1 to 3.

Table 3.8

Data Analysis Method of Each Research Questions

Research Questions	**Statistical Analysis**
1. Is there any significant improvement between pre-test and post-test of the control group Year Four pupils' fraction achievement?	Paired-sample T-test / Wilcoxon signed-rank test
2. Is there any significant improvement between pre-test and post-test of the experimental group Year Four pupils' fraction achievement?	Paired-sample T-test / Wilcoxon signed-rank test
3. Is the fraction achievement of Year Four experimental group pupils in the post-test significantly greater than the control group pupils?	ANCOVA / Mann-Whitney U Test

If the result of the test is significant for research question 1, ANCOVA will be used for research question 3 because the differences exist between the two groups. However, if the results of the test is non-significant in research question 1, then the paired-sample t-test will be conducted. But in this case, if it was a non-parametric data, the Mann-Whitney U Test will be used in research question 3 instead.

3.10 Summary

In this chapter, the researcher presented the introduction, research design, population and sample, data collection, instrument, instructional activities, reliability and validity of research and data analysis method. The research design is a quasi-experimental study which consists of an experimental group and a control group. A total of 56 pupils were selected from one of the national Chinese primary school in Kuala Lumpur. The pupils in the experimental group were taught using the digital game app as the intervention whereas the pupils in control group were taught using the traditional approach like chalk and talk which was based on textbooks only. A pre-test and post-test were given to pupils before and after the pupils completed the instructional activities. The researcher collected data through the analysis of the pre-test and post-test. The data obtained was analyzed with using inferential statistics and is reported in the next chapter, which is chapter Four. The research findings are based on the research methodology in chapter Three.

Chapter 4

FINDINGS

4.1 Introduction

This chapter presents the analysis of the Fraction Achievement Test that corresponds to the three research hypotheses of this study. The first section discusses the results of the descriptive analysis of the Fraction Achievement Test of the experimental group and the control group. The second section addresses the inferential analysis of Fraction Achievement Test of the experimental group and control group. The last section summarizes the chapter.

4.2 Descriptive Analysis of Fraction Achievement Test

The Fraction Achievement test is a pre-test and post-test adapted from National Assessment of Educational Progress (NAEP) and conducted by the researcher to gather information for 56 pupils. The researcher managed to collect information from all pupils in the tests. Before the intervention was conducted, the pupils in both the control and experimental group sat for the pre-test. After the pupils in the experimental group received the interventions, both groups retook the test (post-test). The pupils in the experimental group were not allowed using the Zapzapmath app when answering the test. The demographic information is added in Table 4.1.

Table 4.1

Demographic Information

Demographic	Variables	Experimental Group		Control Group	
Gender	Male	12	42.86%	17	60.71%
	Female	16	57.14%	11	39.29%

The pupils who answered eight out of 10 items correctly for items 1 to 10 were assumed to have mastered the visualization level of fraction concept (Level 1). If the pupils could answer 16 out of 20 items or above out of a total of 20 items, the pupils were assumed to have mastered the analysis knowledge level in fraction (Level 2). However, the pupils who were unable to answer eight out of 10 items correctly for items 1 to 10 were graded as Level 0.

After the Fraction Achievement Test was conducted, the frequency and percentage of the pupils in the control and experimental group who acquired Level 0, Level 1 and Level 2 in the pre-test and post-test were calculated and as shown in Table 4.2.

Table 4.2

The Frequency of the Pupils in the Experimental Group and the Control Group Who Acquire Level 0, Level 1, and Level 2 in the Pre-Fraction Achievement Test and Post Fraction Achievement Test

Fraction Achievement Test	**Groups**	**Fraction Achievement Levels**					
		Level 0		Level 1		Level 2	
		f	%	*f*	%	*f*	%
Pre-test	Experimental (n = 28)	21	75.0	7	25.0	0	0.0
	Control (n = 28)	22	78.6	6	21.4	0	0.0
Post-test	Experimental (n = 28)	1	3.6	7	25.0	20	71.4
	Control (n = 28)	21	75.0	7	25.0	0	0.0

Before the intervention was conducted, the pre Fraction Achievement Test was given to pupils of both control group and experimental group to look at the initial Achievement Levels in Fraction. In the pre-test, there were 21 (75.0%), 7 (25%), and none (0%) of the pupils in the experimental group acquired Fraction Achievement Level 0, Level 1 and Level 2 respectively. Besides that, there were 22 (78.6%), 6 (21.4%), and none (0%) of the pupils in the control group acquired Fraction Achievement Level 0, Level 1 and Level 2 respectively. Based on Table 4.2, it has shown that none of the pupils can achieve Level 2 as they could not answer 16 and above out of 20 items of the pre achievement test. Besides that, it also showed that the pupils in the experimental group and the pupils in the control group have similar basic knowledge in fraction after the pre-Fraction Achievement Test was given.

After the intervention using Zapzapmath app, 20 (71.4%) of the pupils in the experimental group had acquired Fraction Achievement Test Level 2 but only one (3.6%) of the pupils was still at Level 0. There were seven (25.0%) pupils in the experimental group who achieved Fraction Achievement Test Level 1. Besides that, none (0%) of the pupils in the control group has achieved Fraction Achievement Test Level 2 after the teaching of fraction with using the traditional approach. However, 21 (75.0%) pupils in the control group was still at Level 0. There were 7 (25.0%) pupils in the control group who have achieved Fraction Achievement Test Level 1. The results showed that the pupils in the experimental group performed better than the pupils in the control group in post-Fraction Achievement Test. Therefore, it could be interpreted that using digital game-based application like Zapzapmath app had helped to enhance the pupils in the experimental group to gain higher levels of fraction knowledge compared to the pupils in the control group who were taught by using the traditional approach. Teaching using the traditional teaching approach might not be suitable for all the pupils. However, as compared to the digital game-based application using Zapzapmath app, results showed that it was a more effective teaching method to guide pupils to achieved higher level in Fraction Achievement Test. Table 4.3 illustrated a change in Achievement levels in Fraction among the pupils in both the experimental and the control groups.

4.3 Inferential Analysis of Fraction Achievement Test

To derive research question 1, “Is there any significance improvement between pre-test and post-test of the control group Year Four pupils’ fraction achievement?” The researcher analysed the data using descriptive statistics by finding the mean and standard deviation before and after intervention, as tabulated in Table 4.3. Then, the data was also analysed in inferential statistics using paired-samples t-test to test the researcher’s hypotheses stated earlier in the study. The pair-sample t-test results is tabulated in Table 4.4.

Table 4.3
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
PreTest	28	3.00	9.00	5.82	1.85
PostTest	28	3.00	14.00	6.18	2.48
Valid N (listwise)	28				

Table 4.3 shows the mean score of the pre-test and post-test in control group after the traditional teaching approach. It shows the magnitude of the difference between the tests and can be seen which test has a higher mean. The post-test has higher mean (M = 6.18, SD = 2.48) than the pre-test (M = 5.82, SD = 1.85).

Table 4.4

Tests of Normality

	Shapiro - Wilk		
	Statistics	df	Sig.
PreTest	.94	28	.09
PostTest	.91	28	.02

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

One of the requirements of the test conducted in the study is normality, to check whether the scores in the population were normally distributed. Therefore, the study administered a normality test. Table 4.4 shows the normality test table regulated for the paired-sample t-test.

The total number of participants in the control group were 28 pupils, which was below than 50. Hence, Shapiro-Wilk was used to check the normality. Based on Table 4.4, Shapiro-Wilk test examined whether the scores of pre-test and post-test in the control group were significantly different from a normal distribution. The null hypothesis for the pre-test, the sample data of the pre-test was not significantly different than normal distribution, failed to be rejected since the difference was 0.09 which was more than the alpha level 0.05. Hence, the scores in the pre-test were normally distributed.

On the other hand, the null hypothesis for the post-test after the traditional teaching approach was not normally distributed. Based on Table 4.4, the null hypothesis for the post-test in the control group had been rejected since the significant difference was 0.02 which was less than the alpha level 0.05. Therefore, the assumptions of normality were not met and it was violated. The data distribution of the post-test in the control group does not demonstrate a normal distribution.

Besides that, the results of testing the assumptions of the post-test of control the group revealed that there was an outlier, as assessed by the boxplot (See Appendix H). One outlier was detected which was more than 1.5 box-lengths from the edge of the box in a boxplot. The outlier was not considered extreme enough to unduly influence the results and are kept in the analysis. In this case, in order to deal with the outlier, a Wilcoxon sign-rank test was used as an alternative method to replace the paired-sample t-test. The reason is because the Wilcoxon signed-rank test was not affected by outliers to anywhere near the same degree as the paired-sample t-test, so this could be a suitable analysis strategy (Laerd Statistics.com, 2020).

The Wilcoxon signed-rank test was used to determine whether there was a mean difference between the paired or matched observations (Laerd Statistics.com, 2020). This test can be considered as the nonparametric equivalent to the paired-sample t-test. The participants are the same individuals who tested on two different conditions on the same dependent variable. Therefore, Wilcoxon signed-rank test was used to determine the mean difference between pre-test scores and post-test scores of the control group Year Four pupils' fraction achievement test.

The results of the Wilcoxon signed-rank test for the median difference in pre-test and post-test fraction achievement for control group was analysed in Table 4.5. The results showed that the difference in median was .00. Which means the median did not increase in pre-test scores and post-test scores of the control group Year Four pupils' fraction achievement. Hence, Wilcoxon signed-rank test determined that there was no median increase in the fraction achievement (*Mdn Difference*= .00) from pre-test scores (*Mdn* = 5.50) to post-test scores (*Mdn* = 6.00), but this difference was not statistically significant, z = -1.04, p = 0.30. The difference scores were approximately symmetrically distributed, as assessed in a histogram with superimposed normal curve (See Appendix H).

Table 4.5

Results of Wilcoxon Signed-Rank Test for the Median Difference in Pre and Post Fraction Achievement Test for Control Group

Pre-test Control Group	Post-test Control Group	Difference
5.50	6.00	.00

Table 4.6

Results of the Wilcoxon Signed-Rank Test for the Difference in Pre and Post Fraction Achievement Test for the Control Group

		N	Mean Rank	Sum of Ranks	*z*	Asymp.Sig. (2-tailed)	*r*
Post	Negative Ranks	8^{a}	10.81	86.50	-1.04^{d}	0.30	-0.20
FRAT	Positive Ranks	13^{b}	11.12	144.50			
-Pre	Ties	7^{c}					
FRAT	Total	28					

Notes: [a] PostFRAT ‹ PreFRAT; [b] PostFRAT › PreFRAT; [c] PostFRAT = PreFRAT; [d] Based on negative ranks

According to Table 4.6, there were seven tied ranks in which the pupils had obtained the same fraction achievement before and after using traditional teaching approach. Thirteen pupils gained improvement in the fraction achievement test and eight of the pupils had no improvement in the fraction achievement test after the intervention. Based on Rosenthal (1991), the effect size for the control group using the traditional approach was 0.20, which was smaller. Accordingly, the result of Wilcoxon signed-rank test had analysed that there was no significant difference between the means of the pre-test and post-test of the pupils in the control group (z = -1.04, p = 0.30). This showed that the control group's fraction achievement increased at the end of the traditional teaching approach showed no changes within six weeks after the intervention.

The results suggested that the researcher has failed to reject the null hypothesis, when it was at 5% significance level. Therefore, it concluded that the mean of the post-test scores and the mean of the pre-test scores of Year Four pupils in the control group showed no difference. It can be said that the traditional teaching approach was not effective on pupils' fraction achievement levels.

Question 2: *Is there any* significant *improvement between pre-test and post-test of the experimental group Year Four pupils' fraction achievement?*

H_0 : The mean of post-test scores and the mean of the pre-test scores of Year Four pupils in experimental group using Zapzapmath application are not different.

H_1 : The mean of post-test scores is greater than the mean of pre-test scores of Year Four pupils in experimental group using Zapzapmath application.

To answer research question 2, the researcher analysed the data using Wilcoxon signed-rank test since the results of Research Question 1 used a non-parametric method which was equivalent to the paired-sample t-test to find out the significant improvement between the pre-test and post-test scores of experimental group Year Four pupils' fraction achievement. The researcher analyzed the data using descriptive statistics by finding the means and standard deviations before and after intervention of experimental group, as tabulated in Table 4.7.

Table 4.7
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
PreTest	28	3.00	9.00	5.79	1.87
PostTest	28	4.00	20.00	16.39	3.27
Valid N (listwise)	28				

Table 4.7 shows the mean score of the pre-test and post-test in experimental group after the Zapzapmath application. It shows the magnitude of the difference between the tests and can be seen which test has a higher mean. The post-test has higher mean (*M* = 16.39, *SD* = 3.27) than the pre-test (*M* = 5.79, *SD* = 1.87).

Table 4.8
Tests of Normality

	Shapiro - Wilk		
	Statistics	df	Sig.
PreTest	.93	28	.07
PostTest	.81	28	.00

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The assumptions of normality were tested to check whether the score in the population was normally distributed. Thus, the study administered the normality test. Table 4.8 shows the normality test table regulated for paired-samples t-test.

The total number of participants in the experimental group were 28 pupils, which was below 50. Therefore, Shapiro-Wilk was used to check the normality. Based on the Table 4.8, Shapiro-Wilk test examined whether the scores of pre-test and post-test in experimental group were significantly different from a normal distribution. The null hypothesis for the pre-test, the sample data of pre-test was not significantly different than a normal distribution, failed to be rejected since the difference is 0.07

which is more than the alpha level 0.05. Hence, the scores in the pre-test were normally distributed.

Besides that, the null hypothesis for the post-test after the digital game-based approach was not normally distributed. Based on the Table 4.8, the null hypothesis for the post-test in the experimental group had been rejected since the significance differences was .00 which was less than the alpha level 0.05. Therefore, the assumptions of normality were not met and it was violated. The data distribution of post-test in the experimental group was not equal to a normal distribution.

Besides that, the results of testing the assumption for post-test of experimental group revealed that there was an outlier, as assessed by boxplot (See Appendix H). One outlier was detected which was more than 1.5 box-lengths from the edge of the box in a boxplot. The outlier was not considered extreme enough to unduly influence the results and are kept in the analysis. In this case, in order to deal with the outlier, a Wilcoxon sign-rank test was used as an alternative method to replace the paired-sample t-test. The reason is because the Wilcoxon signed-rank test was not affected by outliers to anywhere near the same degree as the paired-sample t-test, so this could be a suitable analysis strategy (Laerd Statistics.com, 2020). Hence, the Wilcoxon signed-rank test was used to determine the mean difference between pre-test scores and post-test scores of the experimental group Year Four pupils' fraction achievement test.

The results of the Wilcoxon signed-rank test for median difference in pre-test and post-test fraction achievement for experimental group was analysed in Table 4.9. The results showed that the difference in median was .00. This meant that the median increase in pre-test scores and post-test scores of the experimental group Year Four pupils' fraction achievement. Hence, Wilcoxon signed-rank test determined that there was a median increase in fraction achievement (*Mdn Difference*= -11.00) from pre-test scores (*Mdn* = 5.50) to post-test scores (*Mdn* = 17.00), but this difference was statistically significant, z = -4.56, p ‹.001. The difference in scores was approximately symmetrically distributed, as assessed by a histogram with a superimposed normal curve (See Appendix H).

Table 4.9

Results of Wilcoxon Signed-Rank Test for the Median Difference in Pre and Post Fraction Achievement Test for Experimental Group

Pre-test Experimental Group	**Post-test Experimental Group**	**Difference**
5.50	17.00	.-11.00

Table 4.10

Results of the Wilcoxon Signed-Rank Test for the Difference in Pre and Post Fraction Achievement Test for the Experimental Group

		N	**Mean Rank**	**Sum of Ranks**	***z***	**Asymp.Sig. (2-tailed)**	***r***
Post	Negative Ranks	0^a	.00	.00	-4.56^d	‹.001	-0.86
FRAT	Positive Ranks	27^b	14.00	378.00			
-Pre	Ties	1^c					
FRAT	Total	28					

Notes: [a] PostFRAT ‹ PreFRAT; [b] PostFRAT › PreFRAT; [c] PostFRAT = PreFRAT; [d] Based on negative ranks

When Table 4.10 was analysed, there were only one tied rank in which one pupil had obtained the same fraction achievement test before and after using digital game-based approach. There were 27 pupils in the experimental group who had improvements in fraction achievement test and none of the pupils achieved lower scores in the fraction achievement test after the intervention. Based on Rosenthal (1991), the effect size for the experimental group with using the digital game-based learning approach was 0.86, which was larger. Accordingly, the results of the

Wilcoxon signed-rank test had analysed that there was a significant difference between the means of the pre-test and post-test of the pupils in experimental group (z = -4.56, $p < .001$). The result showed that the experimental group's fraction achievement at the end of the digital game-based learning approach experienced a great change within six weeks after the intervention.

The result suggested to reject the null hypothesis, when it was at 5% significance level. Therefore, it was concluded that the mean of post-test scores was greater than the mean of pre-test scores of Year Four pupils in the experimental group using the Zapzapmath application. It can be said that the usage of a digital game-based approach is effective on pupils' fraction achievement levels.

Question 3: *Is the fraction achievement of Year Four experimental group pupils in the post-test significantly greater than the control group pupils?*

H_0: The mean of post-test fraction achievement of Year Four experimental group pupils and the control group pupils are not different.

H_1 : The mean of post-test fraction achievement of Year Four experimental group pupils is higher than the control group pupils.

To answer research question 3, the researcher analysed the data using Mann-Whitney U Test to compare the significant improvement between the pupils in both the experimental and control group in the post fraction achievement test. Since the results of the normality test in post-test was violated, then it was considered as a nonparametric data. Therefore, the Mann-Whitney U test was used as the nonparametric alternative to the ANCOVA. The Mann-Whitney U test was a rank-based nonparametric test (Laerd Statistics, 2020) that can be used to determine if there were differences between two groups on a continuous or ordinal variable.

The Mann-Whitney U test is suitable to be used in this study because it has met the assumptions of the Mann-Whitney U Test. Firstly, the dependent variables were continuous. For example, the dependent variables included the pre-test and post-test fraction achievement which was measured using scores. Secondly, the independent variable was an unrelated group but from the same population. For example, the independent variables that met this criterion were the control group and the experimental group.

Next, the third assumption of Mann-Whitney U test was the test on independence of observations which means that there was no relationship between the observations in each groups of the independent variables. For example, there must be different participants in each group with no participant being in more than one group (Laerd Statistics, 2020). In this study, participants of the control group and experimental group were randomly assigned from two classes without participating in more than one group. It is important to meet this assumption of the Mann-Whitney U test.

Lastly, the assumptions of Mann-Whitney U Test were used to determine whether the distribution of scores for both groups of independent variables for example control group and experimental group have the same or different shape. The data obtained was analyzed using SPSS and the results are shown in Table 4.11.

Table 4.11

Result of Mann-Whitney U Test (U) for the Experimental Group and the Control Group in Post Test Fraction Achievement

Pre Achievement Test	**Group**	**Mean**	**Mdn**	**Mean Rank**	***z***	***U***	***p***	***r***
Pretest	Experimental (n = 28)	15.67	17.00	39.75	-5.56	52.50	‹.001	-0.74
	Control (n = 28)	6.23	6.00	15.52				

The mean of the experimental group (39.75) was higher than the mean of the control group (15.52) indicated that the pupils in the experimental group possessed higher scores in post-test fraction achievement than the pupils in the control group after using the digital game-based approach in learning fraction. The effect size in this study is -0.74, which indicated that both the groups had medium effect on pupils' fraction knowledge and skills in post fraction achievement test as the r value was below the -0.8 criterion for a medium effect size based on Rosenthal (1991).

Based on the Table 4.11, the Mann-Whitney U Test was applied to test if there were differences in fraction achievement scores of Year Four pupils between the control and experimental group. Since the shapes of the distributions of post-fraction achievement scores for the two group were not similar (see Appendix H), it can be concluded that the post-test for the experimental group (*Mdn* = 17.00) and control group (*Mdn* = 6.00) were significantly different, $U\ (n_1 = 28, n_1 = 28)$ = 52.50, z = -5.56, p ‹ .001.

The results indicated that the pupils in the experimental group scored significantly higher in the test as compared to the pupils in the control group after the intervention at 5% significance level. Hence, the null hypothesis is rejected (see

Appendix H). The alternative hypothesis is accepted which means that the mean of post-test fraction achievement of Year Four experimental group pupils was higher than the control group pupils. Thus, it could be interpreted that using the digital game-based application – Zapzapmath application in teaching fraction had helped improving pupils' fraction knowledge and skills more significantly than teaching fraction through the traditional approach.

4.4 Summary

Based on the results of the descriptive analysis of research question 1, the control group pupils have scored better in post-test compared to pre-test after traditional teaching approach. However, when Wilcoxon signed-rank test were applied in this study, it indicates there were no any significant difference between the means of pre-test and post-test of control group. The results showed that the control group's fraction achievement gained at the end of traditional teaching approach had no changes within six weeks after the intervention. Next, the descriptive and inferential analysis of the second research question found out that the experimental group scored better in the post-test than the pre-test after receiving treatment using digital game-based app in learning fraction. The experimental group had achieved a higher mean in the post-test than the mean of the pre-test scores of Year Four pupils. The results of the Wilcoxon signed-rank test showed that there was a significance difference in post-tests between the control group and experimental group of Year Four pupils in fraction achievement. Finally, the Mann-Whitney U test also revealed that the pupils in the experimental group possessed significantly higher scores than the pupils in the control group after the intervention. Further discussions, conclusions and implications made based on the research findings are explained in Chapter Five.

CHAPTER FIVE

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

5.1 Introduction

This study was conducted to examine the effectiveness of digital game-based learning in enhancing Year Four pupils' achievement in fraction. In this chapter, the researcher summarized the important ideas of this research. The first section is about the summary of the study that presents findings to answer the research questions. Next, the second section evaluates the summary of the findings based on the objectives of the study. This chapter also presents a comprehensive discussion from major findings of the research and provide the conclusions. The third section discusses the implications based on the results analyzed. Finally, the last section of the chapter looks into the recommendations for further research.

5.2 Summary of the Study

The main purpose of this study is to investigate the effectiveness of digital game-based learning in enhancing Year Four pupils' achievement in fraction. The study was hypothesized as following:

1) The pre-test and post-test of the control group Year Four pupils' fraction were not different.

2) The pre-test and post-test results of the experimental group Year Four pupils' fraction were significantly different.

3) The Year Four pupils' post-test fraction achievement scores between he experimental group and control group were significantly different.

A quasi-experiment was conducted in a Chinese Primary School in Wilayah Persekutuan Kuala Lumpur. 56 Year Four pupils participated in this research and they were chosen as research samples using convenience sampling. Next, the pupils were divided into two groups, a control group and an experimental group. Each group had 28 pupils. The instrument used in this study was the Fraction Achievement Test.

This study was fully conducted by researcher. Instructional activities for experimental group was designed based on the Information Processing Theory and the Gagne's Nine Event of Instructions that included content, goal, features, interaction, feedback and application of knowledge. The scope and content of the instructional materials include fraction knowledge based on the Year Four Mathematics syllabus. A module of teaching and learning fraction knowledge design based on Zapzapmath application was also used to guide the pupils about the content that they should learn from the activities. The instructional materials were used in the mathematics class of the experimental group over a period of six weeks. Instructional activities and the module using Zapzapmath application allowed pupils to investigate, interact, discover relationships, explain and justify their own thinking through discussions to understand the concept and knowledge of fraction in a more sequential way.

Simultaneously, the researcher used a Year Four Mathematics textbook and the worksheets were adapted from the textbook then modified by researcher to teach the concept and knowledge of fraction to the pupils in the control group. The pupils in the control group received the traditional teaching approach for about six weeks. The pupils were not allowed to use computers during the instructional process.

Before the intervention, both groups of pupils sat for the pre-test. After that, the pupils of the experimental group received the intervention for six weeks whereas the pupils of the control group studied fraction through the traditional method. Both groups of pupils sat for the post-test after the interventions.

The significance of the difference in the pre and post fraction achievement test between the pupils in the experimental group and control group were determined using Wilcoxon signed-rank tests and Mann-Whitney U tests.

5.3 Summary of Findings and Discussion

The study had successfully shown how a digital game-based learning can be used in enhancing Primary Four pupil's achievement in fraction. The summary of the research findings is presented accordingly based on the research questions.

Question 1: Is there any significant improvement between pre-test and post-test of the control group Year Four pupils' fraction?

The results of the Wilcoxon signed-rank test on the pre-test and post-test of fraction achievement in the control group of Year Four pupils were not different significantly. Even though, the control group pupils achieved higher in the post-test after receiving the traditional approach as compared to pre-test before the intervention but the difference was not significant. The results showed that the Year Four control group pupils did not gain any improvement at the end even when the traditional teaching approach was applied within six weeks in learning fraction.

This finding is also similar with the study conducted by Hung, Huang & Hwang (2014), which found that the pre-test scores of the control group did not appear to have significance differences before the study was conducted, although the pupils in the control group seemed to perform slightly better than in post-test compared to pre-test. Similarly, Riconscente (2013) had conducted a study at School B, the fraction test was administered using the IPad device as digital game-based learning tool and pupils were not timed. Scores for each pupil were calculated by summing up the correct correspond and dividing by the total number of questions. The result showed that the pupils in the control group did not differ significantly between pre-test and post-test.

Besides that, we would notice that the pupils' initial fraction achievement test which included four subtopics such as part-whole fraction, equivalent and partitioning fraction, comparing fraction and operations of fraction which includes addition and subtraction were ranged from Level 0 to Level 2. This finding is consistent with the study conducted by Idris (2011) regarding the addition and subtraction of fraction on Form Two pupils. However, the initial performance of fraction among Form Two pupils in the study conducted by Idris (2011) acquired Level 1 before the study was conducted. Similarly, in the study of Aksu (2001) who reported that the pupils' initial fraction achievement test ranged from Level 0 (low), Level 1 (average) and Level 2 (high) was not different significantly between the pupils in the control group before the study was conducted.

Question 2: Is there any significant improvement between pre-test and post-test of the experimental group Year Four pupils' fraction achievement?

The results of the Wilcoxon signed-rank test revealed that the pupils in the experimental group had improved significantly in terms of their post fraction achievement test after the Zapzapmath application was conducted. This result was consistent with the findings in the previous study that the pupils in the experimental group scored significantly higher in the post-test as compared to their results in the pre-test after playing the Motion Math game which was related with fractional activities (Riconscente, 2013) and a model based instructional activity (Simsek, 2016). This result was expected as the pupils were taught using digital game-based learning as a teaching approach, which was recognized that it could help pupils to experience and build upon their understanding to see how different mathematical operations are related. Additionally, the digital game-based learning like Zapzapmath application allows pupils to try over and over again until they have mastered the fraction concept and knowledge without time limitation. The consequences of failure are low, it encouraged the pupils to learn from their mistakes and recall the fraction concept used in the game. Therefore, pupils learned new skills or solve fraction problems with the help of game-playing.

According to the study of Mack (2001), pupils need appropriate representations such as pictorial representations to build correct conceptual knowledge and skills. It can help pupils to use their mental construction to construct different characteristics of fraction concepts and knowledge as well. By teaching fraction using game-based apps, pupils could model the process of moving two addends to create a sum. Next, they can see that addends become parts of the same whole. During the process of learning, pupils can determine how to represent that sum symbolically. Through the interventions, pupils gained the opportunity to try out an answer and receive the feedback quickly. This understanding can help to discourage common fraction error during the game play. Thus, when primary pupils at their young age engage in learning fraction concepts and knowledge through visual representations, it can help them to gain higher achievements in fraction (Wilkerson et al., 2015).

Besides that, the pupils gained improvements through the interventions because they managed to transfer new knowledge together by following the nine instructions of events based on the theory, "Cognitive Information Processing Theory and Gagne's Conditional Learning Theory". Correspondingly, pupils managed to complete the instructional activities and post-test given without any help from the teacher and others; this was predicted as the data following characteristics of both theories in this study. Hence, the theories play a crucial role in influencing the research study.

Question 3: Is the fraction achievement of Year Four experimental group pupils in the post-test significantly greater than the control group pupils?

Results of the Mann-Whitney test on pupils' post fraction achievement test suggested that the pupils through digital game-based learning (Zapzapmath application) performed significantly better than the pupils who were taught using the traditional approach with 5% level of significance. It seemed that the digital game-based learning approach was more effective than the teaching of fraction using the traditional approach in enhancing the Primary Four pupil's achievement in fraction.

This result is parallel to the study conducted by Janneth and Dennis (2019) which reported that using digital game-based learning as a teaching approach is effective in enhancing pupils' achievement scores in mathematics. They further explained that the pupils in the experimental group obtained higher achievement scores as compared to the pupils in the control group who were exposed to the learning of fraction inside the classroom with only textbooks and worksheets. This finding is in line with the study conducted by Pili and Aksu (2013) who also reported that pupils who were exposed to digital game-based learning had gained better achievement scores than the pupils who were exposed to the traditional method of teaching. This finding was also supported by Turgut & Dogan Temur (2007) who explained that the integration of digital game-based learning in teaching fraction was found to have a positive effect on the pupils' achievement. Majority of the pupils enjoyed playing and solving the fraction problems during the process.

Besides that, a past research done by Simsek (2016) also supported that the instruction using game-based apps in which the results of the study showed significant improvement of the pupils' knowledge of comparisons, estimation, identification and counting of numbers in the topic of fraction. In this study, the Zapzapmath application was designed to provide the opportunities for pupils to see the pattern of fraction during gameplay. For example, the game relates the conceptual knowledge of fraction as parts of whole. When a half part was separated from a whole, the symbol changed from $\frac{2}{2}$ to $\frac{1}{2}$. Thus, after playing the game, pupils in the experimental group were able to recognize fraction represented in pie shapes, $\frac{3}{5}$ as a fraction with three out of five parts shaded, $\frac{5}{6}$ as a fraction with five out of six parts shaded, and a pie with three out of four parts shaded to represent an exact fraction of "$\frac{3}{4}$" . Hence, pupils were able to recognize different types of representations of fraction in a visual format. Additionally, using the Zapzapmath app can encourage pupils to imagine fraction more flexibly.

The pupils in the experimental group managed to perform better than the pupils in the control group because the intervention of using digital game-based learning was designed for the pupils in the experimental group based on the theories, "Cognitive Information Processing Theory and Gagne's Conditional Learning Theory". The learning was more pupils-centered whereas the teachers play an important role to facilitate the pupils in developing, applying and adapting to the new knowledge through the instructional activities and discussions. Thus, the pupils were able to understand each level of difficulty and challenge in fraction then link their prior knowledge to a new understanding of the concept and knowledge in the learning process (Eggen & Kauchak, 2007); which is in line with the Cognitive Information Processing Theory and Gagne's Conditional Learning Theory. However, the control group used the traditional method where the teacher taught fraction by chalk and talk in the class (Riconscente, 2013). As a result, pupils in the experimental group performed better than the pupils in the control group after the intervention.

5.4 Implications

5.4.1 Implications for Instruction

In this study, the treatment session was carried out for pupils in the experimental group. There was a total of twelve lessons that were planned to help pupils learn fraction with using digital game-based learning as a teaching approach. Based on the results obtained, as explained in Chapter 4, pupils in the experimental group after using the Zapzapmath app performed better than the pupils in the control group after using the traditional method. From the results obtained, some of the implications can be deduced for curriculum developers, teachers, mathematics education, mathematics coordinators, pupils and mathematics curriculum researchers.

Firstly, the improvement difference in post fraction achievement test between the experimental group and the control group was significant had suggested that the instruction using the digital game-based app like the Zapzapmath application was more effective in enhancing primary four pupils' achievement in fraction as compared to the traditional approach. This result might encourage more primary school teachers to use the digital game-based ad teaching tool while the teaching of the topic of fraction could be more interesting and meaningful teaching and learning experience for primary school pupils.

This result is consistent with the study conducted by Mitchell and Savill-Smith (2004), which reported that the pupils in the experimental group showed a better achievement in fraction compared to the pupils in the control group after the Grade 4 pupils was taught using the digital game-based app. Mitchell and Savill-Smith (2004) also found that the digital game-based apps can help pupils improve enhancing and retention of prior knowledge, develop the social and cognitive skills through the interaction and solving problems in a game.

Similarly, the result of the study is in line with the study conducted by Hung, Huang & Hwang (2014), which aimed to enhance primary pupils' achievement in fraction through digital game-based learning. They found that the digital game-based learning apps as teaching instructions had successfully enhanced primary school pupils' achievement in fraction significantly. Thus, they concluded that the digital game-based learning app was effective as a learning tool for teachers and pupils in learning fraction as it promotes motivation and supports pupils to highly engage in a game towards learning.

Based on the significance of the study in Chapter 1, the curriculum developers will get an idea of including technology which is using game apps like Zapzapmath app in the mathematics textbook. As the results shown in this study, by using digital game-based learning app like Zapzapmath will enhance pupils' interest and motivation to learn mathematical skills and knowledge. Therefore, curriculum developers can consider adding a technological tool in this topic to make learning more interesting and meaningful. Besides that, curriculum developers can attach the instructions of using the Zapzapmath app in the topic of fraction to guide pupils to follow and create the opportunity for pupils to expand their understanding through exploring.

Besides that, curriculum developers can take into an account of adding the instructions on how to use Zapzapmath app in learning fraction in the teachers' mathematics reference books. With this opportunity, teachers may get new ideas from mathematics reference books and create new activities for pupils to explore new understandings. Teachers can gain some knowledge on how to use the game apps and practice it before applying the teaching method in class. Therefore, teachers will not be left behind in terms of using technology if this app was included in the curriculum.

On the other hand, mathematic educators or teachers will gain benefits from this study too. As the results were obtained in this study, it has proven that the pupils in the experimental group have performed better after using the Zapzapmath app during the intervention. Therefore, teachers are encouraged to implement the digital game-based learning as a tool in teaching fraction. By improving teachers' professional development, teachers can consider using the digital game-based learning as a teaching approach in their classes. In this 21st century, there are many educational organizations who provide different kinds of courses in helping teachers to upgrade their knowledge and skills in using the technology the teaching and learning of mathematics. In that case, the mathematics leaders or coordinators in schools should provide courses or training for teachers in order to help them improve their teaching pedagogy and also for their professional development as well.

In addition, teachers can use the theories of Cognitive Informative Processing Theory and Gagne's Conditional Learning Theory as a guide to teach fraction when using the technology. This teaching method highly encourages pupils to retrieve new information and apply their prior knowledge during the intervention, and obtain new knowledge based on that by reflecting on the processes of solving the fraction problems. It is also proven in this study that pupils showed interest in learning fraction with the use of the Zapzapmath app in class. Therefore, teachers play crucial roles in motivating the pupils and facilitating them to develop their knowledge with technology.

Moreover, learning fraction by digital game-based learning will bring benefit to pupils. The first reason is pupils will be motivated to use the Zapzapmath app to challenge their skills and knowledge from the simplest level to the most challenging level. They are able to win at every level in the game app. The second reason is they tend to be engaged in the lesson during the intervention where the pupils have discussions about fraction among their peers. The last reason is pupils are trained to provide reasoning about their understanding towards the concept of fraction and justify the conclusion during the intervention class.

Finally, the study will benefit the mathematics curriculum researchers as the study had discussed some recommendations to do their research in future. This research helps the mathematics curriculum researches to develop novel ideas to further their research to fill up the research gap.

5.4.2 Implications for Theory Development

5.4.2.1 Cognitive Information Processing Theory

Firstly, the significant improvement in primary pupils' achievement in fraction between the experimental group and the control group supported the major assumption of the cognitive information processing theory which is the learners are learning fraction actively and they can learn to enhance and retention of prior knowledge, develop cognitive skills and social skills through the discussion and solve the problem in a game (Mitchell & Savill-Smith, 2004). In this study, the pupils in the experimental group improved their achievement in fraction using digital game-based learning apps as the teaching approach and they have completed the instructional activities without any help from others. By comparing to the pupils in the control group, they improved their achievement using the traditional method and they complete the worksheets given with optimal guidance from the teacher. Based on the Fraction Achievement Test given to pupils, both groups of pupils gained improvement from the instructional activities designed specifically for them.

Besides that, the findings from this study implies that the pupils' fraction knowledge are built based on his or her own experience (Cunningham et al., 2007). When pupils learn new knowledge by relating to the previous learned knowledge, their mind would help them promote multiple connections between the new and prior knowledge (Eggen & Kauchak, 2007). Lester et al. (2014) further suggested that when pupils were able to acquire, store and retrieve the knowledge, they would relate the new information to the previous information already stored in memory, it would be easier for pupils to remember and learn the knowledge more effectively.

In the Zapzapmath app – the Fast Fraction Line, players need to drag the spaceship to the correct location based on the fraction given. Through this game, pupils explore fraction with the same denominators and figure out the pattern of fraction on the number line. Pupils were able to store new knowledge when seeing $\frac{0}{4}$ is the same as 0 and $\frac{4}{4}$ is the same as 1. By relating the new information to the previous information, pupils learn how to compare the fraction by using the number line. For example, pupils can relate the concept that $\frac{3}{4}$ is closer to $\frac{4}{4}$ or one whole by using the Fast Fraction Line in the game. An immediate feedback was given when pupils select the answer to ensure the pupils understand the concept of comparison fraction correctly (Gagne et al, 2005). Therefore, the cognitive information processing theory plays an important role to assist pupils' learning and consolidate their understanding as well.

5.4.2.2 Gagne's Conditional Theory

Based on the obtained result, it was clearly shown that the difference between the pre-test and post-test of the experimental group of Primary Four pupils' achievement in Fraction was significant, suggested that by applying the Conditional Learning Theory of Gagne into the digital game-based learning of Zapzapmath app was effective in enhancing primary year four pupils' achievement as compared to the traditional method. The findings of this study were consistent with a study carried by (Brown et al, 2009). The study was proven to give a positive impact, according to the theory of Gagne et al. (1992), the conditions of learning theory describes levels of learning as an instructional design that should allow the interactions and environmental stimuli to bring about changes in the cognitive structures and operations of the learners. Results showed that by applying the Conditional Learning Theory of Gagne in digital game-based learning of the Zapzapmath app can support pupils' achievement in fraction; pupils can organize and restructure the knowledge, analysing and applying the previous concepts then making connections between the concepts and knowledge. It is in accordance with Gagne's theory of learning that it is believed that every child has different cognitive abilities, that learning is a process of behavioural changes of an organism as a result of experience, it is permanent but not only temporarily, and learning to solve problems, the rules obtained are used to solved the problems (Erlinda & Surya, 2017).

The pupils from the experimental group showed improvement through a stimulus (digital game-based learning) where they were able to solve problems through their own experiences. While the theory of learning had an impact on pupils, every instruction turns out to be a process to help pupils link new information on relevant concepts contained in a person's cognitive structure (Erlinda & Surya, 2017). Past research by Simsek (2016) strongly supported the findings too. He explained that with the support of the Conditional Learning Theory of Gagne in game-based apps, the results of the study showed significant improvement of the pupils' knowledge of comparisons, estimation, identification and counting of numbers in the topic of fraction. On the other hand, it also showed that by engaging with the theory with the game-based learning apps had helped pupils gain better understanding about the magnitude of rational numbers such as fraction. The gap achievement of pupils with the learning theory in digital game-based learning apps has steadily increased over time. Hence, the conditional learning theory of Gagne plays an effective way to provide learners with opportunities to engage in responding to mathematic tasks with useful feedback thereby increasing the level of proficiency and skills at their own pace.

Based on the above opinion, it can be concluded that enhancing pupils' achievement in fraction with the Conditional Learning Theory of Gagne in digital game-based apps is an interesting and non-boring learning model in improving the knowledge of fraction. The study is also supported by Mitchell and Savill-Smith (2004), by applying the Conditional Learning Theory of Gagne in digital game-based learning apps can help pupils improve enhancing and retention of prior knowledge, develop the social and cognitive skills through the interaction and solving problems in a game. Thus, the Conditional Learning Theory of Gagne and digital game-based learning was effective as a learning tool for teachers and pupils in learning fraction as it promotes motivation and supports pupils' engagement in cognitive thinking skills towards learning mathematics.

5.5 Recommendations for Further Study

According to the findings of this study and its implications, the research needs to be carried out further by integrating the technology as learning tools into teaching and learning mathematics in future. The following recommendations have been made for further research that add to general knowledge on the teaching and learning of mathematical knowledge and skills. There are many further studies that could be conducted as a follow up to further investigate the effectiveness of digital game-based learning as a teaching approach and its interaction with different standards of pupils' in fraction skills.

Secondly, the research can focus on different scopes in terms of demographic background. The pupils involved as participants in this study were conveniently sampled from a Chinese Primary School in Wilayah Persekutuan Kuala Lumpur. For future studies, it is recommended to choose samples from International schools or other public school from other states in Malaysia.

Thirdly, in terms of mathematical content, this study focused on general fraction skills in part-whole fraction, equivalent fraction, comparing fraction and operation fraction like addition and subtraction. For future studies, it is recommended to focus on another specific fraction content like operations of fraction using multiplication and division to investigate pupils' knowledge and skills.

In terms of data collection method, this study employed a quasi-experimental research design. For future studies, it is recommended that to employ a mixed method research design with the aim to find different outcomes concerning pupils' fraction skills especially in an environment using technology as a teaching and learning tool.

Finally, it is recommended that further studies be conducted to investigate the effectiveness of using digital game-based learning as a teaching approach between Year 5 or Year 6 pupils with different knowledge and skill levels (low, moderate and high) and find out their attitudes towards learning fraction with technology tools after the treatment sessions in the future. The treatment in this study was conducted in six weeks with 12 lessons. It is recommended that the future studies can consider a prolonged treatment period for stronger input especially the effect of using digital game-based learning may be boosted as the length of the treatment is increased. It also helps pupils to become a good problem solver and increase their confidence in completing mathematical tasks in the future. Therefore, there is a strong need to recommend that the future studies to investigate the effectiveness of using digital game-based learning as a teaching approach in increasing Year 5 and Year 6 pupils' confidence in their mathematical skills and knowledge and also to find out the pupils' attitudes towards learning fraction skills through digital game-based learning in class.

5.6 Contributions of the Study

This study has important contributions for improving pupils' achievement in fraction. Based on the results obtained in this study, it had proven that using digital game-based apps in the teaching and learning process could improve pupils' achievement in fraction. Pupils are able to define fraction, numerator, denominator, identifying the number shaded part, recognize the number of equals parts in s shape, show awareness that one whole can be represented by many fraction, makes comparison between different fraction, identify the equivalent fraction are equal, and recognize that only the numerator should be added or subtract but not the denominators. Besides that, pupils in the experimental group could perform better than the control group. They were exposed to a real-life situation to explore and learn the fraction skills through the game apps. Therefore, this study encourages the use of suitable digital game-based apps in the teaching and learning of fraction in future. As the results of this study was positive, it can be a good example for teachers and educators to implement similar technology tool in the teaching and learning of fraction which can help to produce more pupils who can obtain more knowledge and improve their skills in future.

5.7 Conclusions

In conclusion, the results of this study supported the hypothesis that the pupils' achievement in fraction differed significantly before and after the instruction using the Zapzapmath application. Additionally, the fraction achievement test scores between the pupils in the experimental group and the pupils in the control group differed significantly after the instruction with using the Zapzapmath application as well.

Therefore, this study reported that the use of a digital game-based app like the Zapzapmath application is effective in enhancing primary four pupils' achievement in fraction as compared to using the traditional method. The fraction achievement scores of pupils from the experimental group improved significantly after using the Zapzapmath application. It seemed that the module of instructional activities for the experimental group was designed based on the Information Processing Theory and the Gagne's Nine Event of Instructions using the game-based app was useful to guide pupils' learning fraction concept and knowledge as compared to the instruction of the traditional approach. This result is consistent with the study done by Riconscente (2013), which concluded that the primary pupils can gain better understanding through a well-designed module of instructional activities with using digital game-based apps as well as teacher's guidance and facilitation.

On the other hand, the pupils also showed positive learning using digital game-based apps. They were able to spend more time to engage in the learning content in order to increase their opportunity to give feedback and also increased the level of proficiency and knowledge at their own pace through gameplay. The design of the game app also enables pupils to experience a sense of confidence in fraction and be rewarded for success each time they answer every question correctly. The achievement gap between the pupils in experimental group and control group has steadily improved from this study.

This study also proved that the digital game-based learning approach was effective in enhancing fraction achievement for 28 pupils which had significant impact on the pupils in engaging mathematical tasks without requiring much teacher guidance. Results showed that using digital game-based app such as Zapzapmath can develop pupils' fraction concept; organize and restructure the knowledge, analysing and applying the previous concepts then making connections between the concepts and knowledge. Zapzapmath app was able to provide many response opportunities with feedback for pupils who needed it to improve their achievement in fraction. Therefore, this study has given a positive impact concerning the utilization of digital game-based learning in enhancing achievement in fraction among primary four pupils.

REFERENCES

Ahmad, W. F. B. W., & Latih, N. H. B. A. (2010). Development of a Mathematics courseware: Fraction', *Proceedings of the Fifteenth Asian Technology Conference in Mathematics*, Kuala Lumpur, Malaysia.

Akgul, M. B. (2014, January). The effect of using Dynamic Geometry Software On Eight Grade Students' Achievement in Transformation Geometry, *Geometric Thinking and Attitudes Toward Mathematics and Technology*, 1-227.

Aksu, M. (2001). Student performance in dealing with fraction. *The Journal of Educational Research*. *90*(6): 375-380.

Arikunto, S. (2012). *Prosedur Penelitian Suatu Pendekatan Praktik*, Jakarta: PT. Rineka Cipta.

Aslan, S. (2011). *Game Based Improvement of Learning Fraction Using iOS Mobile Devices. Computer Science*. Retrieved from: https://pdfs.semanticscholar.org/8bea/3bdb3d2fadc8e9f34fbd80083e9e4545dd8d.pdf?_ga=2.50776873.160234338.1596292855-613457002.1596292855

Bailey, D. H., Hoard, M. K., Nugent, L., & Geary, D. C. (2012). Competence with fraction predicts gains in mathematics achievement. *Journal of Experimental Child Psychology*, *113*(3): 447– 455.

Bailey, D., Siegler, R. S., & Geary, D. C. (2014). Early predictors of middle school fraction knowledge. *Developmental Science*, *17*(5): 775-785. Retrieved from https://doi.org/10.1111/desc.12155

Barsalou, L. W. & Hale, C. R. (1993). Components of conceptual representation: From feature lists to recursive frames. *In: Categories and concepts: Theoretical views and inductive data analysis*, ed. I. Van Mechelen, J.

Beavis, C. (2015). Multimodal Literacy, Digital Games and Curriculum. *Mathematics Education in the Digital Era*, *4*(1): 109-122.

Becker, K. (2005). How Are Games Educational? Learning Theories Embodied in Games. *DiGRA Conference*. Retrieved from: https://doi.org/10.11575/prism/30342

Beckmann, S. (2008). *Mathematics for elementary teachers* (2nd ed). Boston: Addison Wesley, 1-256.

Behr, M.J., Lesh R., Post, T. R., & Silver E. A. (1983). *Rational Numbers concepts. Acquisition of Mathematics Concepts and Processes*, New York: Academic Press, 91-125. Retrieved from http://www.cehd.umn.edu/ci/rationalnumberproject/83_1.html

Behr, M. J., Harel, G., Post, T., & Lesh, R. (1992). Rational number, ratio and proportion. Dlm. D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics,* 209-33.

Belgin, B., & Esen. E. (2017). Developing An Achievement Test For Fraction Teaching: Validity And Reliability Analysis. *ITM Web Conferences*, *13*(01003). Retrieved from https://www.itm-conferences.org/articles/itmconf/pdf/2017/05/itmconf_cmes2017_01003.html

Berlinghoff, W. P., & Gouvea, F. Q. (2004). *Math through the ages: A gentle history for teachers and others*. Farmington, ME: Oxton House Publishers.

Booth, J. L., & Newton, K. J. (2012). Fraction: Could they really be the gatekeeper's doorman?. *Contemporary Educational Psychology*, *37*(4): 247– 253.

Boticki, I., Looi, C.K., & Wong, L.H. (2010). Doing collaboration and learning fraction with mobile devices. *Proceedings of Global Chinese Conference on Computers in Education 2010*, 9-15. Singapore.

Brijlall, D., Maharaj, A., & Molebale, J. (2011). Understanding the Teaching and Learning of Fraction: A South African Primary School Case Study. *US_China Education Review A*, *4*: 497-510. Retrieved from https://eric.ed.gov/?id=ED526785

Brown, D., Shopland, N., Battersby, S., Tully, A., & Richardson, S. (2009). Game On: accessible serious games for offenders and those at risk of offending. *Journal of Assistive Technologies*, *3*(2): 13-25. Retrieved from https://doi.org/10.1108/17549450200900012

Bulgar, S. (2003). Children's sense-making of division of fraction. *Journal of Mathematical Behavior*, *2:* 319–334

Case, R., & Bereiter, C. (1984). From behaviourism to cognitive behaviourism to cognitive development: Steps in the evolution of instructional design. *Instructional Science*, *13*(2): 141–158. https://doi.org/10.1007/BF00052382

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research on teaching*. Boston: Houghton Mifflin.

Chair, C. P. B., Embretson, S., Fennell, F. S., Fristedt, B., Loveless, T., Schmid, W., Stotsky, S., Arispe, I., & Kelly, I. D. (2016). Chapter 8: Report of the Task Group an Assessment. *Task Group Reports of the National Mathematics Advisory Panel*. Retrieved from https://www2.ed.gov/about/bdscomm/list/mathpanel/report/assessment.pdf

Chan, S. W., & Ismail, Z. (2014b). A Technology- Based Statistical Reasoning Assessment Tool In Descriptive Statistics for Secondary School Students. *The Turkish Online Journal of Educational Technology, 13*(1): 18.

Charles, T., Bustard, D. W. & Black, M. M. (2011). Experiences of promoting student engagement through game-enhanced learning. *Serious Games and Edutainment Applications*, 425–445.

Chua, Y.P. (2013). *Mastering research methods*. Shah Alam: McGraw-Hill Education.

Clark, R. E. (2007). Learning from serious games? Arguments, evidence and research suggestions. *Educational Technology*, 56-59.

Clark, R. C., & Mayer, R. E. (2011). *E-Learning and the Science of Instruction*. San Francisco: Pfeiffer.

Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences, 2nd Edition. Routledge "*Correlation and Linear Regression*" in Mangiafico, S.S. 2016. *Summary and Analysis of Extension Program Evaluation*, version *1*(13). Retrieved from: http://rcompanion.org/handbook/I_10.html .

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. London: Sage publications.

Creswell, J. W. (2014). *Qualitative inquiry & research design: Choosing among five approaches* (2 ed.). London: Sage publications.

Cunningham, W., Zelazo. P., Packer. D., & Van Bavel. J. (2007). The Iterative Reprocessing Model: A Multilevel Framework for Attitudes and Evaluation. *Social Cognition - SOC COGNITION*, *25*: 736-760. Retrieved from https://doi.org/10.1521/soco.2007.25.5.736.

de Castro, B. V. (2008). Cognitive Models: The Missing Linkto LEarning Fraction Multiplication and Division. *Asia Pacific Education Review, 9*(2): 101-112.

Divjak, B., & Tomic, D. (2011). The Impact of Game-Based Learning on the Achievement of Learning Goals and Motivation for Learning Mathematics – Literature Review. *Journal of Information and Organization Sciences*, *35*(1): 15-30.

Doğan, M., & Içel, R. (2011). The role of dynamic geometry software in the process of learning: GeoGebra example about triangles. *International Journal of Human Sciences*, *8*(1). Retrieved from : http://www.InsanBilimleri.com/En

Effandi, Z., Lu, C. C, & Md. Yusoff, D. (2010). The Effects of Cooperative Learning on Students' Mathematics Achievement and Attitude towards Mathematics. *Journal of Social Sciences*, *6*(2): 272-275.

Eggen, P. D., & Kauchak, D.P. (2007). *Strategies and Models for Teachers Teaching Content and Thinking Skills*, 5th edition, Pearson Education Inc.

Erdem, E., Gokkurt, B., Şahin, O., Basibuyuk, K., Nergiz, T., & Soylu, Y. (2015). Examining Prospective Elementary Mathematics Teachers' Modeling Skills of Multiplication and Division in Fraction. *Croatian Journal of Education*. Retrieved from: https://doi.org/17. 10.15516/cje.v17i1.830.

Erlinda, N & Surya. E. (2017). Mathematical Learning Strategy of Fractional form by Using Learning Model of Gagne and Human Figure Line Media. *International Journal of Sciences: Basic and Applied Research (IJSBAR)*, *34*(2): 13-22.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2014). Teacher Technology Change: How Knowledge, Confidence, Beliefs and Culture Intersect. *Journal of Research on Technology in Eduction*, *42*(3): 255-284.

Etikan, I., Musa, A., & Alkassim, R. S. (2016). Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1): 1-4. doi: 10.11648/j.ajtas.20160501.11

Fazio, L., & Siegler, R. (2015). Teaching fraction. *The International Academy of Education*, 1-28.

Franco, Creso & Sztajn, Paola & Ortigão, Maria. (2007). Mathematics Teachers, Reform, and Equity: Results from the Brazilian National Assessment. *Journal for Research in Mathematics Education*, *38*(4).

Fregola, C. (2015). Mathematics and Educational Psychology: Construction of learning Environments. *Mathematics Education in the Digital Era*, *4*(1): 175-196.

Fuson, K.C., & Beckmann, S. (2012). Standard algorithms in the Common Core State Standards. *National Council of Supervisors of Mathematics Journal of Mathematics Education Leadership*, *14*(2): 4–30.

Gagne, R. M. (1985). *The conditions of learning theory of instruction* (4th ed.). New York: Holt, Rinehart, and Winston.

Gagne, R. M., Briggs, L. J., & Wager, W. W. (1992). *Principle of instructional design (4th ed)*. Forth Worth, TX: Harcourt Brace Javanovich College Publishers. Retrieved from https://www.niu.edu/facdev/_pdf/guide/learning/gagnes_nine_events_instruction.pdf

Gagne, R.M.,& Medsker, K.L, (1996). The conditions of learning: Training implications. Chapter 11, *The events of instruction*, 138-152. Orlando: Harcourt Brace.

Gagne, R. M., Wager, W.W., Golas, K. C. & Keller, J. M (2005). *Principles of Instructional Design(5th edition)*. California: Wadsworth.

Gee, J. P. (2003). *What videogames have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Goba, B., Balfour, R. J., Nkambule, T. (2011). The nature of experimental and quasi-experimental research in postgraduate education research in South Africa: 1995-2004. *SAJHE*, *25*(2): 947-964. Retrieved from https://www.researchgate.net/publication/293568405_Goba_Balfour_Nkambule

Goh. S. Y. (May, 2015). *M-learning application for PT3 Mathematics (Solid Geometry)*. Faculty of Information and Communication Technology (Perak Campus). Retrieved from http://eprints.utar.edu.my/1825/1/IA-2015-1103933-1.pdf

Gokalp, N. D., & Sharma, M. D. (2010). A study on addition and subtraction of fraction: The use of Pirie and Kieren model and hands-on activities. *Procedia-Social and Behavioral Sciences*. *2*(2): 5168-5171. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877042810008803

Grabbe J.W. (2015) Implications of Experimental versus Quasi-Experimental Designs. *The Palgrave Handbook of Research Design in Business and Management*, In: Strang K.D. (eds), Palgrave Macmillan, New York.

Gros, B. (2010). Game-Based learning: A strategy to integrate digital games in schools. *Technology Implementation and Teacher Education: Reflective Models*, 365-379.

Gros, B. (2015). Integration of Digital Games In Learning and E-learning Environments: Connecting Experiences and Context. *Mathematics Education In The Digital Era 4*, 36-53.

Gupta, D., & Wilkerson, T. (2015). Chapter 2: Teaching And Learning of Fraction in Elementary Grades. *In Let the Dialogue Begin!*, 27-44.

Guven, B., & Kosa, T. (2008). The Effect of Dynamic Geometry Software on Students Mathematics Teachers' Spatial Visualization Skills. *The Turkish Online Journal of Educational Technology-TOJET*, *7*(4).

Hassan, S., Rosli, R., & Zakaria, E. (2016). The Use of i-Think Map and Questioning to Promote Higher-Order Thinking Skills in Mathematics. *Creative Education*, *7*(7), 1069-1078. Retrieved from http://dx.doi.org/10.4236/ce.2016.77111

Henry, Gary T. (1990). Practical Sampling. 21. London: Sage Publications.

Hiebert, J., & Carpenter, T. P. (1992). Learning and teaching with Understanding. *Handbook of research on mathematics teaching and learning*. New York: Mcmillan, 65-97.

Hung, C. M., Huang, I., & Hwang, G. J. (2014). Effects of digital game-based learning on students' self-efficacy, motivation, anxiety, and achievements in learning mathematics. *Computers & Education*, *1*(2-3): 151-166.

Hunting, R. P. (1983). Alan: a case study of knowledge of units and performance with fraction. *Journal for Research in Mathematics Education*, *14*: 182-197.

Hussain, S. Y., Hoe, T. W., & Idris, M. Z. (2017). Digital game based learning: A new method in teaching and learning mathematics. *AIP Conference Proceedings 1847*: *030016*. Retrieved from https://doi.org/10.1063/1.4983894

Hwang, G. J., & Wu, P. H., (2013). Advancements and trends in digital game-based learning research: A review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology*, *43*(1): E6-E10.

Hwang, G, J., Wu, P. H., & Chen, C. C. (2012). An online game approach for improving students' learning performance in web-based problem-solving activities. *Computers & Education*, *59*(4): 1246-1256.

Idris, N. (2011). Error Patterns in Addition and Subtraction of Fraction among Form Two Students. *Journal of Mathematics Education*, *4*(2): 35-54.

Instructional Assessment Resources. (2011). *Item Analysis. Retrieved from University of Texas at Austin, Instructional Assessment Resources*, IAR Web site: http://www.utexas.edu/academic/ctl/assessment/iar/students/report/itemanalysis.php

Isiksal, M., & Cakiroglu, E. (2011). The nature of prospective mathematics teachers' pedagogical content knowledge: the case of multiplication of fraction. *J Math Teacher Education*, 213- 230.

Jack, R. F., Norman, E. W., & Helen, H. H. (2015). *How to Design and Evaluate Research in Education (Ninth Edition ed.)*. New York: McGraw Hill Education.

Janneth, R., & Dennis, R. (2019). Game-Based Design Mathematics Activities And Students' Learning Gains. *The Turkish Online Journal of Design Art and Communication*. *9*: 1-7.Retrieved from: https://doi.org/10.7456/10901100/001.

Kaasila, R., Pehkonen, E., & Hellinen, A. (2010). Finnish Pre-Service Teachers' and Upper Secondary Students' Understanding of Division and Reasoning Strategies Used. *Educational Studies in Mathematics, 73*(3): 247-261.

Kadijevich, D. (2005). Towards Basic Standards for Research In Mathematics Education. *The Teaching of Mathematics*, *8*(2): 73-81. Retrieved from http://elib.mi.sanu.ac.rs/files/journals/tm/15/tm823.pdf

Kafai, Y. B., Franke, M. L., Ching, C. C., & Shih, J. C. (1998). Game design as an interactive learning environment for fostering students' and teachers' mathematical inquiry. *International Journal of Computers for Mathematical Learning*, *3*(2): 149-184.

Kathirveloo, P., & Puteh, M. (2014). Effective Teaching: Pedagogical Content Knowledge. *Proceeding of International Joint Seminar Garut*, Indonesia, 1-7.

Khairunnisak, C., Maghfirotun, S., Juniati, A. D., de Haan, D. (2012). Supporting Fifth Graders in Learning Multiplication of Fraction with Whole Number. *Indonesian Mathematical Society Journal on Mathematics Education*, *3*(1): 71-86. Retrieved from https://eric.ed.gov/?d=Ej1078650

Kickmeier-Rust, M, D., Mattheiss, E., Steiner, C., Albert, D. (2011). A psycho-Pedagogical Framework for Multi-Adaptive Educational Games. *International Journal of Game-Based Learning*, *1*(1): 45-58. Retrieved from https://eric.ed.gov/?id=Ej1113737

Kiryakova, G., Angelova, N., & Yordanova, L. (2014). Gamification in Education. *Conference: 9th International Balkan Education and Science Conference*, Edirne Turkey. Retrieved from https://www.researchgate.net/publication/320234774

Laerd Statitics. (2020). Retrieved from https://statistics.laerd.com/

Lampert. M. (1990). When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal*, *27*(1): 29-63.

Lamon, S. J. (1999). *Teaching fraction and ratios for Understanding*. Mahwah, NJ: Lawrence Erlbaum Associates.

Larkin, K. (2015). "An App! An App! My Kingdom for An App": An 18-Month Quest to Determine Whether Apps Support Mathematical Knowledge Buiding. *Mathematics Education in the Digital Era*, *4*(1): 251-276.

Lee, H.J., & Boyadzhiev, I. (2013). Challenging Common Misconceptions of Fraction through GeoGebra. In R. McBride & M. Searson (Eds.), *Proceedings of SITE 2013--Society for Information Technology & Teacher Education International Conference*, 2893-2898. Retrieved from https://www.learntechlib.org/primary/p/48531/.

Lester, J. C., Spires, H. A., Nietfeld, J. L., Minogue, J., Mott, B. W., & Lobene, E. V. (2014). Designing game-based learning environments for elementary science education: A-narrative-centered learning perspective. *Information Sciences*, *264*: 4-18. Retrieved from https://www.intellimedia.ncsu.edu/wp-content/uploads/lester-is-2013.pdf

Li, Y., & Smith, D. (2007). Prospective Middle School Teachers' Knowledge In Mathematics and Pedagogy for Teaching - The Case of Fraction Division. *Proceedings of the 31st Conference of the International Group for the Psychology of Mathematics Education*, *3*: 185-192.

Little, T. W. (2015). Effects of Digital Game-Based Learning on Student Engagement and Academic Achievement. *Source: Dissertation Abstracts International*, *77*(01): 146 – 220.

Lin, C. Y., Becker, J., Byun, M. R., Yang, D. C., & Huang, T. W. (2013). *Preservice Teachers' Conceptual and Procedural Knowledge of Fraction Operations: A Comparative Study of the United States and Taiwan*, *113*(1): 41-51. Retrieved from https://doi.org/10.1111/j.1949-8594.2012.00173.x

Logan, T., & Woodland, K. (2015). Digital Games and Mathematics Learning: The State of Play. *Mathematics Education in the Digital Era*, *4*(1): 277-303.

Lowrie, T. (2015). Digital Game, Mathematics and Visuospatial Reasoning. *Mathematics Education in the Digital Era*, *4*(1): 71-92.

Lowrie, T., & Jorgensen, R. (2015). Digital Games and Learning: What's New Is Already Old?. *Mathematics Education in the Digital Era*, *4*(1): 1-9.

Mack, N. K. (1990). Learning fraction with understanding: Building on informal knowledge. *Journal for Research in Mathematics Education*, *21*: 16-32.

Mack, N. K. (1995). Confounding whole number and fraction concepts when building on informal knowledge. *Journal for Research in Mathematics Education*, *26*: 422-441.

Mack, N. K. (2001). Long-term effects of building on informal knowledge in a complex content domain: The case of multiplication of fraction. *Journal of Mathematical Behavior, 19*(2000): 307-332.

Malaysia Education Blueprint. (2013). Malaysia Education Blueprint 2013-2025 (Preschool to Post-Secondary Education). *Kementerian Pendidikan Malaysia*, Putrajaya, 1-292.

Martin, T., Petrick, S. C., Forsgren, N., Aghababyan, A., Janisiewicz, P. & Baker, S. (2015). Learning Fraction by Splitting: Using Learning Analytics to Illuminate the Development of Mathematical Understanding. *Journal of the Learning Sciences*, *24*(4): 593-637.

Martinez-Mesa, J., Gonzalez-Chica, D. A., Duquia, R. P., Bonamigo, R. R., & Bastos, J. L. (2016). Sampling: how to select participants in my research study?. *An Bras Dermatol*. *91*(3): 326–330. https://doi.org/10.1590/abd1806-4841.20165254

Mayer, R. E. (1996). Learning strategies for making sense out of expository text: The SOI model for guiding three cognitive processes in knowledge construction. *Educational Psychology Review*, *8*: 1-371.

McNamara, J., & Shaughnessy, M. M. (2010). *Beyond pizzas and pies: 10 essential strategies for supporting fraction sense (grades 3–5)*. Sausalito, CA: Math Solutions Publications.

Mehdiyev, R. (2009). *Exploring participants' learning experiences when using a Dynamic Geometry Software (DGS) tool in geometry class at a secondary school in Azerbaijan*. AMSTEL Institute Universities Amsterdam: The Netherlands.

Mercer, T. G., Kythreotis, A. P., Robinson, Z. P., Stolte, T., George, S. M., & Haywood, S. K. (2016). The Use of Educational Game design and Play in Higher Education to Influence Sustainable Behaviour. *International Journal of*

Sustainability in Higher Education, *18*(3): 359-384. Retrieved from https://doi.org/10.1108/IJSHE-03-2015-0064

Ministry of Education (2003). *Kurikulum bersepadu sekolah rendah: Sukatan pelajaran matematik*. Kuala Lumpur: Pusat Perkembangan Kurikulum.

Misquitta, R. (2011). A Review of the Literature: Fraction Instruction for Struggling Learners in Mathematics. *Learning Disabilities Research & Practice, 26*(2): 109-119.

Mitchell, A., & Savill-Smith, C. (2004). *The use of computer and video games for learning: A review of the literature*. London, England: Learning and Skills Development Agency. Retrieved from http://dera.ioe.ac.uk/5270/1/041529/pdf

Mousley. K., & Kelly. R. R. (2018). Developing Deaf Students Fraction Skills Requires Understanding Magnitude and Whole Number Divisions. *Journal of Education and Learning*, *7*(2): 12-20. Retrieved from: http://doi.org/10.5539/jel.v7n2p12

Moutinho, L., & Hutcheson, G. (2011). *The SAGE Dictionary of Quantitative Management Research*. London: SAGE Publications Ltd.

Moyer, P. S., & Mailey, E. (2004). Inchworm and a Half: Developing Fraction and Measurement Concepts Using Mathematical Representations. *Teaching Children Mathematics*, VA: NCTM, 244-252.

Mugo, F.W. (2002). *Sampling in research*. Retrieved from: http://neumann.hec.ca/sites/cours/51-651-02/Sampling_in_Research.htm

Mullis, I. V. S., Martin, M. O., Foy, P., & Arora, A. (2012). TIMSS 2011 International Results in Mathematics. *MA: TIMSS & PIRLS International Study Center*, Boston College. Retrieved from https://eric.ed.gov/?id=ED544554

Mullis, I. V. S., & Martin, M.O. (2013). *TIMSS 2015 Assessment Frameworks. TIMSS & PIRLS International Study Center*, Boston College. Retrieved from http://timssandpirls.bc.edu/timss2015/frameworks.html

Mullis, I. V. S., Martin, M.O., Foy. P., & Hooper. M. (2015). *TIMSS 2015 International Result in Mathematics. TIMSS & PIRLS International Study Center*, Boston College. Retrieved from http://timssandpirls.bc.edu/timss2015/international-results/wp-content/uploads/filebase/full%20pdfs/T15-International-Results-in-Mathematics-Grade-8.pdf

Mullis, I. V. S., Dossey, J. A., Owen, E. H., & Phillips, G. W. (1993). NAEP 1992 mathematics report card of the nation and the states (Rep. No.23-ST02). *National Center for Education Statistics*, Washington, DC: U. S. Department of Education.

Myers, J. L., Well, A. D., & Lorch, R. F. Jr. (2010). *Research design and statistical analysis (3rd ed.)*. New York, NY: Routledge.

National Assessment of Education Progress. (2014). NAEP Question Tool Grade 4 - 8. *National Center for Education Statistics*, Washington: U.S. Department of Education. Retrieved from https://nces.ed.gov/NationsReportCard/nqt/Search

NAEP Technical Documentation. (2017). NAEP scoring. *National Center for Education Statistics*. Washington: U.S. Department of Education. Retrieved from https://nces.ed.gov/nationsreportcard/tdw/scoring/

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.

National Mathematics Advisory Panel (NMAP). (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel*. Washington, D.C.: U.S. Department of Education.

Nazirah, M. S., Talib, O., & Norishah, T. P. (2013). Merging of Game Principles and Learning Strategy using Apps for Science Subjects to Enhance Student Interest and Understanding. *Jurnal Teknologi*, *63*(2): 7-12.

Newstead, K. (1998). Aspects of Children's Mathematics Anxiety. *Educational Studies in Mathematics*, *36*: 53-71. Retrieved from: https://doi.org/10.1023/A:1003177809664Games. DiGRA Conference. Retrieved from: https://doi.org/10.11575/prism/30342

Newton, K. J. (2008). An Extensive Analysis of Preservice Elementary Teachers' Knowledge of Fraction. *American Educational Research Journal, 45*(5): 1080.

Niemi, D. (1996). A fraction is not a piece of pie: assessing exceptional performance and deep understanding in elementary school mathematics. *Gifted Child Quarterly*, *40*(1): 70-80.

Nunnally, J. C. (1978). *Psychometric theory. 2nd Edition*, McGraw-Hill, New York.

Olanoff, D., Jane Lo, J., & Tobias, J. M. (2014). Mathematical Content Knowledge for Teaching Elementary Mathematics: A Focus on Fraction. *The Mathematics Enthusiast, 11*(2): 267-310.

Olofson, M. W., Meredith, J. C. S., & Maureen, D. N. (2016). TPACKing: A constructivist framing of TPACK to analyze teachers' construction of knowledge. *Computers & Education*, *96*: 188-201. Retrieved from https://doi.org/10.1016/j.compedu.2015.12.010

Osman, K., & Bakar, N. A. (2012). Implementation of Educational Computer Games in Malaysia Chemistry Classroom: Challenge for Game Designers. *Recent Researches in education*. Retrieved from http://www.wseas.us/e-library/conferences/2011/Penang/EDU/EDU-18.pdf

Ovwigho, B.O. (2013). Empirical Demonstration of Techniques for Computing the Discrimination Power of a Dichotomous Item Response Test. *IOSR Journal of Research and Method in Education*, *3*(2): 12-17

Pantziara, M., & Philippou, G. (2012). Levels of students'"conception" of fraction. *Educational Studies in Mathematics*, *79*(1): 61-83.

Park, J., Gucler, B., & McCrory, R. (2012). Teaching Prospective Teachers about Fraction: Historical and Pedagogical Perspectives. *Educational Studies in Mathematics*, *82*(3): 455-479. Retrieved from https://scholars.opb.msu.edu/en/publications/teaching-prospective-teachers-about-fraction-historical-and-peda-3

Periasamy, D., Bakar, K. A., & Ayub, A. F. (2014). Effects of MATAS Hopscotch Technique in the Teaching of Fraction and Error Patterns Made by Year 5 Pupils. *Education Research International*, *2014*(2014): 1-8. Retrieved from http://dx.doi.org/10.1155/2014/630721

Pilli, O. (2008). *The effects of computer-assisted instruction on the achievement, attitudes and retention of mathematics in 4th grade courses*. Doctoral dissertation. Available from Council of Higher Education Thesis Center Database in Turkey. (Thesis No. 27694).

Pili, O., & Aksu, M. (2013). The Effects of Computer-Assisted Instruction on the Achievement, Attitudes and Retention of Fourth Grade Mathematics Students In North Cyprus. *Computers & Education*, *62*: 62-71. Retrieved from https://doi.org/10.1016/j.compedu.2012.10.010

Pitkethly, A., & Hunting, R. (1996). A review of recent research in the area of initial fraction concepts. *Educational Studies in Mathematics*, *30*(1): 5-38.

Post, T. R. (1981). Fraction: Results and Implications from National Assessment. *Arithmetic Teacher*, *28*: 26-31.

Prensky, M. (2001). *Digital Game-based Learning*. New York: McGraw-Hill.

Prensky, M. (2001b). Digital natives, digital immigrants. *On the Horizon*, *9*(5): 1-6. doi:10.1108/10748120110424816

Prensky, M. (2005). Computer games and learning: Digital game-based learning. *Handbook of computer game studies*, *18*: 97-122.

Prensky, M. (2008). The role of technology in teaching and the classroom. *Educational Technology*, *48*(6). Retrieved from http://www.marcprensky.com/writing/Prensky-The_Role_of_Technology-ET-11-12-08.pdf

Punzalan, E. M. D., & Buenaflor, R. F. (2017). Modeling the relationship between the basic computational and problem-solving skills of Fourth-Year high school students in the Division of Zambales, Phillippines. *International Journal of Education and Research*, *5*(1): 173-184. Retrieved from http://www.ijern.com/journal/2017/January-2017/15.pdf

Raduan, I. H. (2010). Error Analysis And The Corresponding Cognitive Activities Committed by Year Five Primary Students In Solving Mathematical Word Problems. *Procedia-Social and Behavioral Sciences*, *2*(2): 3836-3838. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877042810006403

Rai, D., Heffernan, N. T., Gobert, J. D., & Beck, J. E. (2009). Mily's World: Math game involving authentic activities in visual cover story. *Proceedings of the Workshop on Intelligent Educational Games at the 14th International Conference on Artificial Intelligence in Education*, 125–128.

Rejeki, S., Setyaningsih, N., & Toyib, M. (2017). Using LEGO for learning fraction, supporting or distracting?. *AIP Conference Proceedings*. 1848: 040016. Retrieved from: https://doi.org/10.1063/1.4983954.

Richey, R. C. (1986). *The theoretical and conceptual bases of instructional design*. New York: Nichols.

Riconscente, M. M. (2013). *Results From a Controlled Study of the iPad Fraction Game Motion Math. Games and Culture*, 186-214. Retrieved from http://journals.sagepub.com/doi/abs/10.1177/1555412013496894

Rosenthal, R. (1991). *Meta-analytic procedures for social research (Rev. ed.)*. Newbury Park, CA: Sage.

Schunk, D. H. (1996). *Learning theories an Educational Perspective (6th ed.)*. Printice Hall Inc., New Jersey

Shellenbarger, S. (2013). Why are fraction key to future math success?. *The Wall Street Journal*. Retrieved from https://www.wsj.com/articles/new-approaches-to-teaching-fraction-1380064772?tesla=y

Shuell, T. J. (1986). Cognitive conceptions of learning. *Review of Educational Research*, *56*: 411–436.

Shuell, T. J. (1988). The role of the student in learning from instruction. *Contemporary Educational Psychology*, *13*: 276–295.

Shuell, T. J. (1996). *Teaching and learning in a classroom context. Handbook of educational psychology*, 726-764, New York, NY, US: Macmillan Library Reference Usa; London, England: Prentice Hall International.

Siegler, R. S., & Forgues, H. L. (2011). Conceptual Knowledge of Fraction Arithmetic. *Journal of Educational Psychology*, 1-41.

Siegler, R. S., & Lortie-Forgues, H. (2015). Conceptual knowledge of fraction arithmetic. *Journal of Educational Psychology*, *107*(3): 909.

Siegler, R. S., Fazio, L. K., Bailey, D. H., & Zhou, X. (2012). Fraction: the new frontier for theories of numerical development. *Trends in Cognitive Sciences*, 1-7.

Simsek, O. (2016). Use of a Game-based App as a Learning Tool for Students with Mathematics Learning Disabilities to Increase Fraction Knowledge/Skill. *Graduate Theses and Dissertations*. Retrieved from http://scholarcommons.usf.edu/etd/6390

Smith, M. L., & Fey, P. (2000). Validity and Accountability in High-Stakes Testing. *Journal of Teacher Education*, *51*(5). Retrieved from https://www.questia.com/library/journal/1G1-66664664/validity-and-accountability-in-high-stakes-testing

Stienstra, W. M. (2014). Developing Understanding: Pre-service Elementary Teachers' Changing Conceptins of Mathematics. *Electronic Theses and Dissertations from 2009*. Retrieved from http://knowledgecomons.lakeheadu.ca/handle/2453/463

Steffe, L. P., & Olive, J. (2001). The problem of fraction in the elementary school. *Journals of the National Council of Teacher of Mathematics*, VA: The NCTM, 128-132.

Suhaidah, T. (2006). *Pemahaman konsep pecahan dalam kalangan tiga kelompok pelajar secara keratan lintang.* Tesis Phd. Universiti Teknologi Malaysia, Skudai, Johor.

Tan. K. J., Ismail. Z., & Abidin. M. (2018). A Comparative Analysis on Cognitive Domain for the Malaysian Primary Four Textbook Series. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(4): 1273 – 1286. Retrieved from : https://doi.org/10.29333/ejmste/82625

Tang, H. E, Voon, L. L, & Nor, H, J. (2010). The Relationships Between Students' Underachievement in Mathematics Courses and Influencing Factors. *International Conference on Mathematics Education Research 2010 (ICMER 2010)*, *8* (2010): 134-141. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877042810021245

Thambi, N., & Leong. K. E. (2013). Effect of students' achievement in fraction using GeoGebra. *SAINSAB*, *16*: 97-106. Retrieved from http://repository.um.edu.my/30704/1/V162013_97to106.pdf

Thompson, P. W., & Saldanha, L. A. (2003). *Fraction and multiplicative reasoning. Research companion to the principles and standards for school mathematics*, 95-113.

Thyer, B. A. (2012). The scientific value of qualitative research for social work. *Qualitative Social Work*, *11*(2): 115-129. Retrieved from http://journals.sagepub.com/doi/abs/10.1177/1473325011433928

Tian, J., & Siegler, R. S. (2016) Fraction learning in children with mathematics difficulties. *Journal of Learning Disabilities*, 1-7. Retrieved from : https://doi.org/10.1177/0022219416662032

TIMSS. (2011). *TIMSS 2011 International mathematics report: Findings from IEA's trends in International mathematics and science study at the fourth and eight grades*. Boston College: TIMSS & PURLS International Study Center.

TIMSS report. (2015). Laporan TIMSS 2015 – Trends In International Mathematics And Science Study. Bahagian Perancangan Dan Penyelidikan. *Kementerian Pendidikan Malaysia*, 1-16, Putrajaya. Retrieved from https://www.moe.gov.my/images/Terbitan/Rujukan Akademik/pubfile_file_002124.pdf

Tirosh, D. (2000). Enhancing prospective teachers' knowledge of children's conceptions: The case of division of fraction. *Journal for Research in Mathematics Education, 31*(1): 5-25.

Triola, M. F. (2011). *Essentials of statistics* (4th ed.). Boston: Addison-Wesley.

Trybus, J. (2009). Game-Based Learning: What it is, Why it Works, and Where it's Going. *New Media Institute*. Retrieved from http://www.newmedia.or /game-based-learning-what-it-is-why-it-works-and-where-its-going.pdf.

Turgut, S.,& Temur, O. D. (2017). The Effect of Game- Assisted Mathematics Education on Academic Achievement in Turkey: A Meta-Analysis Study. *International Electronic Journal of Elementary Education*, *10*(2): 195-206. Retrieved from https://files.eric.ed.gov/fulltext/EJ1165497.pdf

U.S Department of Education. (2004). *The Nation's Report Card: America's Charter Schools (No. NCES 2005-456)*. Washington, DC: National Assessment of Educational Progress. Retrieved from http://nces.ed.gov/nationsreportcard/nde

Van De Walle, J. A., Karp, K. S., & Bay-Williams, J. M. (2012*). Elementary and secondary school mathematics: Teaching with developmental approach*. Ankara: Nobel Academic Publishing.

Van Erk, R. N. (2006). Digital Game-Based Learning: It's Not Just the Digital Natives Who Are Restless. *Educause*, *41*(2). Retrieved from https://www.researchgate.net/publication/242513283

Van Erk. R. N. (2015). SAPS and Digtal Games: Improving Mathematics Transfer and Attitudes in School. *Mathematics Education in the Digital Era*, *4*(1): 141-174.

Vecchia, D, R., Maltempi, M. V., & Borba, M. C. (2015). The Construction of Electronic Games as an Environment for Mathematics Education. *Mathematics Education in Digital Era*, *4*(1): 55-69.

Webster, M. (1985). Webster`s nith new collegiate dictionary. WebsterSAGE Publications.

Westera, Wim. (2015). Games are motivating, aren't they? Disputing the arguments for digital game-based learning. *Internatinal Journal of Serious Games*, *2*(2). Retrieved from https://dspace.ou.nl/bitstream/1820/6126/1/IJSG-Westera-Disputing%20the%20arguments%20for%20digital%20game-based%20learning.pdf

Widjaja, W., & Stacey, K. (2009). Growth of Pre-service Teachers' Knowledge and Teaching Ideas About Decimals and Fraction: The Case of Vivi. *Proceedings of the 32nd annual conference of the Mathematics Education Research Group of Australasia*, 1-8.

Wilkerson, T. L., Cooper, S., Gupta, D., Montgomery, M., Mechell, S., Arterbury, K., Moore, S., Baker, B. R., & Sharp, P. T. (2015). An Investigation of Fraction Models in Early Elementary Grades: A Mixed-Methods Approach. *Journal of Research in Childhood Education*, *29*(1). Retrieved from https://doi.org/10.1080/02568543.2014.945020

Witherspoon, M. L. (1993). Fraction: in search of meaning. *Arithmetic Teacher*, *40* (8): 482-485.

Wong, L.-H., Boticki, I., Sun, J., & Looi, C.-K. (2011). Improving the scaffolds of a mobile assisted Chinese character forming game via a design-based research cycle. *Computers in Human Behavior*, *27*(5): 1783-1793. Retrieved from http://dx.doi.org/10.1016/j.chb.2011.03.005

Yilmaz, G. K. (2015). The Effect of Dynamic Geometry Software and Physical Manipulatives on Candidate Teachers' Transformational Geometry Success. *Educational Science: Theory & Practise*. *15*(5), 1417 – 1435. Retrieved from: https://doi.org/10.12738/estp.2015.5.2610

Yilmaz, C., Lewis, D. M. G., & Al-Shawaf, L. (2015). *The Openness-calibration hypothesis. Personality and Individual Differences*, *81*(2015): 53-60. Retrieved from https://www.researchgate.net/publication/271135022_The_Openness-calibration_hypothesis

Yoshida , H., & Sawano, K. (2002). Overcoming cognitive obstacles in learning fraction: Equal-partitioning and equal-whole. *Japanese Psychological Research,* *44*(4): 183-195. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/1468-5884.00021/epdf

Yusoff, A., Crowder, R., Lester, G., & Wills, G. (2009). A Conceptual Framework For Serious Games. *Ninth IEEE International Conference on Advance Learning Technologies*. Retrieved from https://eprints.soton.ac.uk/267690/1/3711a021.pdf

ZapzapmathOnline. (2018). Retrieved from https://www.zapzapmath.com/

Zhi., H. L. (2014). *A comparison of convenience sampling and purposive sampling*. PubMed, 105-11.

Zimmaro, D.M. (2004). *Writing Good Multiple-Choice Exams: The Division of Instructional and Assessment*, University of Texas

Zin, N. A. M., Jaafar, A., & Yue, W. S. (2009). Digital game-based learning (DGBL) model and development methodology for teaching history. *WSEAS Transactions on Computers*, *8*(2): 322-333. Retrieved from https://ukm.pure.elsevier.com/en/publications/digital-game-based-learning-dgbl-model-and-development-methodolog