THE EFFECTS OF DIGITAL GAME-BASED LEARNING USING MINECRAFT TOWARDS PUPILS' ACHIEVEMENT IN FRACTION

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ABSTRACT

The ability to understand and master concepts of fractions will provide a solid basis for understanding more complex mathematical concepts which in turn will assist in solving problems involving fractions in everyday life. However, findings of the international assessments Trends in Mathematics and Science Studies (TIMSS) and Program for International Student Assessment (PISA) indicated that the achievement of fractions among pupils in Malaysia is at a poor level, which is below the international average score. In considering the rapid development and advancement of digital games, the purpose of this study is to investigate the effect of DGBL using Minecraft on pupils' achievement in fractions. A quasi-experiment with a pre-test and post-test nonequivalent groups was conducted involving 65 Year Five pupils in two intact classes. Through cluster sampling, one class was selected as the treatment group while the other class was selected as the control group. The treatment group which consists of 31 pupils was exposed to DGBL using Minecraft while the control group which consists of 34 pupils was exposed to conventional methods. Data were analyzed using an independent sample t-test to compare the post-test achievement score mean for fraction between the treatment group and the control group. There was a statistically significant difference in the achievement scores mean between the treatment group (mean=8.80, SD=2.77) and the control group (mean=6.20, SD=2.79). The findings from this study would further encourage the use of digital games, especially Minecraft, in the teaching and learning of fractions so as to increase pupils' achievement.

Keywords: DGBL, Minecraft, concepts of fractions, achievement

INTRODUCTION

Fractions are complex but important concepts in mathematics. Understanding of the concepts of fractions is important not only to provide a solid foundation for the formation and development of mathematical ideas (Zakiah et al., 2013) but also to assist in the mastery of other more complex mathematical concepts such as algebraic concepts (Booth et. al., 2014). Furthermore, having a solid knowledge of the concept of fractions will help in solving everyday problems especially those that involve calculations and measurements such as percentages, ratios, rates as well as decimals (Abdul Halim et. al., 2015; Booth et. al., 2014; Ndalichako, 2013; Wijaya, 2017). In Malaysia, based on the mathematics curriculum in the Kurikulum Standard Sekolah Rendah (KSSR), the topic of fractions has been introduced to pupils since Year One (Kementerian Pendidikan Malaysia, 2015). "Fractions" is one of the topics in the domain of Numbers and Operations and is taught after the topic of whole numbers.

Although exposed at an early age, most Malaysian pupils are still having difficulties in learning and mastering the topic. Difficulties encountered in learning fractions have resulted in Malaysian pupils obtaining unsatisfactory level of achievement in fractions (Abdul Halim *et. al.*, 2015). Reports in TIMSS and PISA assessments showed that the average achievement score of Malaysian pupils in mathematics was below the international average score, in which fractions are among the topic tested in the Number domain. Malaysian pupils obtained an average score of 474 in TIMSS 2007, 440 in TIMSS 2011 and 465 in TIMSS 2015 as shown in Table 1. These average scores were well below the international average score of 500 based on the TIMSS International Benchmarks of Mathematics Achievement in Table 2. Based on these scores, Malaysia's performance in TIMSS had slipped to the Low International Benchmarking of Mathematics Achievement (Mullis et al., 2016), an indication that despite investing heavily in education, the return on educational investment in Malaysia was not as high as expected. In PISA 2009 and PISA 2012, Malaysian pupils achieved a score of 404 and 421 in Mathematics Literacy respectively, which was again below the international average score of 548 (Abdul Halim *et. al.*, 2015; OECD, 2013).

Table 1: Malaysia's mathematics average achievement score in TIMSS based on year taken

Year Taken	Average Score
2007	474
2011	440
2015	465

Table 2: TIMSS International Benchmarks of Mathematics Achievement

Level of International Benchmark	Average Score
Advanced International Benchmark	625
High International Benchmark	550
Intermediate International Benchmark	475
Low International Benchmark	400

One of the reasons that contribute to the decline in Malaysia's performance in both international assessments is the pupils' inability to fully grasp the conceptual understanding of fraction, as a result of misconceptions caused by the concepts of whole numbers. Based on the content of KSSR for mathematics, the topic of fractions is taught after the pupils are exposed to whole numbers and the basic operations of addition, subtraction, multiplication and division as well as the combined operations in the Numbers and Operations domain (Kementerian Pendidikan Malaysia, 2014; Noorbaizura & Leong, 2013). The pupils' prior learning of whole numbers and the manner in which fractions are introduced to them at the early stages of

learning of fractions may have affected their conceptual understanding of the proper algorithm to use when solving operations of fractions. They tend to get confused between concepts of fractions and concepts of whole numbers. For instance, in questions involving the addition and subtraction of fractions, the pupils were treating numerators and denominators as separate entities. Pupils assume that the numerator and denominator were two separate integers rather than two numbers that have a relationship with each other (DeWolf & Vosniadou, 2015), thus affecting their ability to solve operations of fractions correctly.

Pupils are simply adding or subtracting the numerators and denominators as they were provided (Dhlamini & Kibirige, 2014; Li, 2014; Loong, 2014; Ndalichako, 2013). It should be noted that when adding or subtracting fractions that have the same denominator, the denominator is maintained and when the denominators are different, the fractions should be converted to equivalent fractions before the operations are carried out. Below are examples of the misconceptions caused by the concepts of whole numbers:

$$\frac{1}{3} + \frac{2}{3} = \frac{3}{6} \quad \text{and} \quad \frac{3}{5} + \frac{2}{3} = \frac{1}{2}$$

These findings clearly showed that pupils lack the conceptual understanding of the concepts of fractions (Almeda & Dy., 2013; Azurah & Effandi, 2015; Bottge et al., 2014; Zakiah et al., 2013). As a result, pupils are bound to find fractions confusing and easily mix them up since they don't have a clear understanding of what fractions and operations of fractions mean. In order to strengthen the pupils' conceptual understanding of fractions and at the same time improve their achievement in fractions, DGBL is seen as an appropriate approach and should be applied to achieve the goals stated above, especially through the use of Minecraft.

LITERATURE REVIEW

Digital games are highly sought after every year, thus, turning the digital games industry into a billion-dollar industry (Malaysian Investment Development Industry, 2020). The Entertainment Software Association (2019) estimated that the sales value of digital games in 2018 in the United States itself exceeds 43.3 billion USD. As many as 165 million or 65% of the adult population in the United States, spanning various age groups, races and genders, play digital games. The average age of individuals playing digital games were 33 years, with the average time spent playing digital games approximately 8.3 hours per week. According to Wijman (2020), the global digital games market will generate a high revenue by 2020 with the reason being that digital games offer something that is highly sought after by every individual; entertainment and satisfaction (Ritterfield & Weber, 2006). The elements of entertainment and satisfaction offered by digital games have contributed to the increasing demand for digital games due to the ability of digital games to attract attention and encourage engagement as well as immersive in nature; reasons as to why people spend long hours playing digital games (Kirriemuir & McFarlene, 2004).

Realizing that digital games are able to trigger high demand among various groups of individuals regardless of gender, ethnic background (Bickham et al., 2003) as well as age (IDSA, 2003), there have been efforts among educators to integrate digital games into the educational environment especially in teaching and learning with the hope that digital games can support and encourage more active involvement of pupils in learning so that the intended learning objectives can be achieved. The integration of digital games into the learning environment has resulted in a teaching and learning method known as DGBL.

DGBL has gained much attention in the educational setting over the past 20 years

(Aishah & Connolly, 2013; All et al., 2014; Boyle et al., 2016; Li & Tsai, 2013; McLaren et al., 2017; Westera, 2015). There is no exact definition to specifically describe DGBL (Huizenga, 2017; Wong & Kamisah, 2018); DGBL is usually defined based on some common features. According to All et al., (2017), DGBL is the use of digital games for educational purposes that combine both entertainment and educational elements. Al-Azawi et al., (2016) define DGBL as the integration of digital games in the teaching and learning session with the aim of enhancing learning experience. As a teaching and learning method that promotes learning through play (Hwang et al., 2015; Yang, 2015), DGBL is applied to make the learning environment more enjoyable than conventional methods (Wang et al., 2011). According to Prensky (2001) and Wiggins (2016), DGBL is a teaching and learning method that involves the combination of game features with teaching content with the goal of achieving the learning objectives. DGBL has the potential to facilitate the development and enhancement of learning performance as this learning method is capable of providing interesting learning experiences that challenge the abilities, encourage engagement and trigger motivation which in turn increase pupils' interest in the subject taught by teachers (Chang et al., 2012; Meluso et al., 2012; Siew et al., 2016). All these features indicate that DGBL promotes pupils-centered learning strategy through the integration of technology into the education system. Pupils-centered learning is a teaching strategy that provides pupils the opportunity to participate actively in the learning process (Bell & Lygo-Baker, 2017) thereby enabling pupils to be more involved in the lesson as the teacher does not dominate the teaching and learning session. This is turn will encourage pupils to develop and generate ideas in order to solve a particular problem.

Most of the studies conducted on DGBL involved various variables such as engagement (Annetta et al., 2010), motivation (Iacovides et al., 2011), learning performance (Chen et al., 2012), cognitive (Kim et al., 2009), creativity (Behnamnia et al., 2020) academic achievement (Chen, 2017; Siew et al., 2016; Yeh et al., 2017) as well as involving a variety of subjects such as English (Yeh et al., 2017), Geography (Khairuddin et al., 2017), Physics (Kao et al., 2017), Mathematics (Ku et al., 2014) and social science (Hwang et al., 2015), All et al., 2014). Specific to the academic achievement, although several studies have been conducted, empirical findings regarding the effect of DGBL on improving pupils' academic achievement needs to be further explored (All et al., 2017). DGBL is seen to have the potential to improve academic achievement considering the ability of this learning method to provide interesting learning experiences, challenge abilities, encourage engagement and generate motivation which will increase pupils' interest in teaching and learning sessions, thus improving academic performance (Chang et al., 2012; Meluso et al., 2012; Siew et al., 2016).

Minecraft as a digital game

Minecraft is a popular 'sandbox' game with over 100 million units sold worldwide. The virtual world created in Minecraft is a 3D block world where players were able to explore and build independently with no clear objectives or targets to be achieved, typical of an open world game (Donellan, 2019). In a virtual Minecraft world, players use various types of blocks, which are cube-shaped, to build various types of objects as well as structures. Minecraft has been used as a teaching tool for a variety of topics and subjects around the world (Ellison, 2016; Short, 2012). Educators have identified several benefits of using Minecraft as a teaching tool and these benefits cover a wide range of fields and subjects such as mathematics (Bos et al., 2014). For example, Minecraft allows a pupil or player to collect, break, reconstruct, remove and place random 3D blocks in a virtual world in order to form any object or structure according to the imagination of the player (Bos et al., 2014; Ekaputra et al.,

2013; Kim & Park, 2009; Lane et al., 2017; Mojang, 2015; Nebel et al., 2016). The ability to manipulate the elements in this virtual world would act as a stimulus for various activities or learning projects and are entertaining and fun at the same time.

Learning of fractions using Minecraft

Most pupils have difficulties in understanding the basic concepts of fractions especially the relationship between the numerator and denominator as well as the concept of equivalent fractions (Rodrigues et al., 2017; Siegler & Pyke, 2013). According to Stafylidou and Vosniadou (2004), pupils view fractions as a pair of numbers representing a particular quantity without understanding that there is a relationship between the two quantities. This misconception has resulted in pupils not having good conceptual understanding and knowledge of fractions (Simon et al., 2018; Zakiah et al., 2013). The use of Minecraft is seen as having the potential to strengthening the conceptual knowledge of fractions as Minecraft allows hands-on manipulation activities to be performed on blocks in the virtual world of Minecraft especially in performing fractional problem solving. In Minecraft, blocks can be arranged to produce structures or objects that represent fractions known as fraction models. Fraction models allow pupils to visualize the value of fractions more easily and clearly which in turn helps them to have a better understanding of the concepts of fractions. For example, in Figure 1, two red blocks placed on top of a transparent block will form a fractional model with a value of $\frac{2}{3}$. The interpretation of the arrangement of blocks is that the three blocks show the value of the denominator while the two red blocks show the value of the numerator. Through hands-on manipulation of these blocks, activities related to basic operations such as adding, subtracting and multiplying of fractions can be performed in Minecraft. This hands-on activity will help to create a relationship between the activity and the concepts of fractions because by performing activities that involve hands-on manipulations, the pupils' mathematical skills will be improved and this in turn helps them to better understand abstract mathematical concepts since they can visualize the concepts clearly in their mind (Holmes, 2013; Kontaş, 2016). Manipulations on materials either in the form of concrete objects or virtual forms will help strengthen the understanding of mathematical concepts (Hartshorn & Boren, 1990). The pupils will also be able to develop complex knowledge through active engagement with manipulatives (Bruner, 1977; Dienes, 1973; Piaget, 1965). Figure 2 shows a fractional problem-solving activity that can be prepared by teachers in Minecraft.

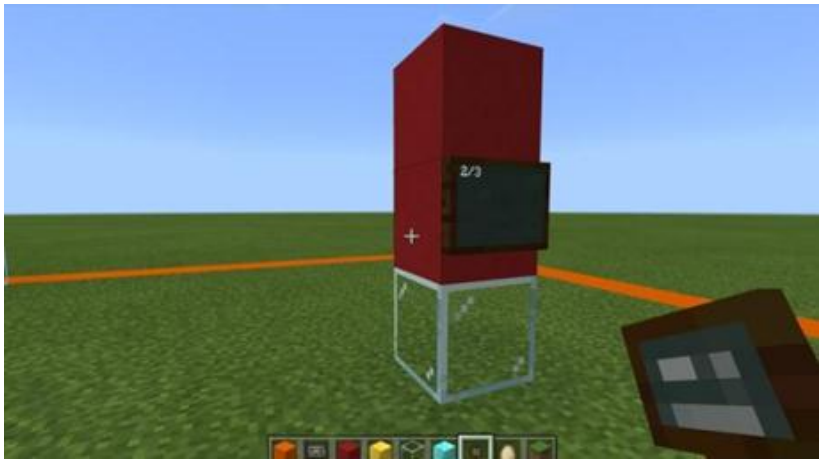

Figure 1: Arrangement of blocks that form the fraction model $\frac{2}{3}$

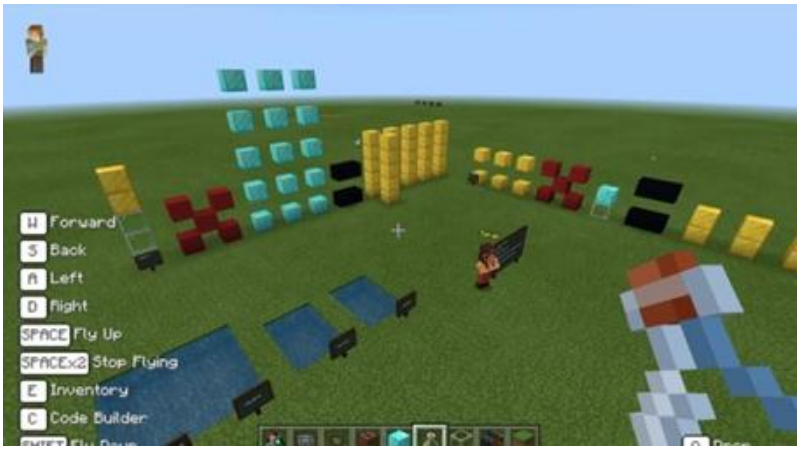

Figure 2: Problem-solving activities using fraction models

Therefore, this study aims to identify the impact of DGBL using Minecraft in improving the achievement of Year Five pupils in fractions. This study was conducted in a primary school in Sabah with the following research hypotheses:

H_o1: There is no significant difference between the pre-test and post-test achievement score mean for the topic of fractions in the control group.

H_o2: There is no significant difference between the pre-test and post-test achievement score mean for the topic of fractions in the treatment group.

H_o3: There is no significant difference in the post-test achievement score mean for the topic of fractions between the control group and the treatment group.

METHODOLOGY

Research design and sample

This study uses a pre-test and post-test quasi-experimental nonequivalent group design. The sample consisted of 65 Year Five pupils from two intact classes in a primary school in Kuala Penyu, one of the districts in Sabah. Through cluster sampling, a class containing 31 pupils was selected as the treatment group while another class containing 34 pupils was selected as the control group. The treatment group was exposed to DGBL while the control group was exposed to conventional teaching methods. The duration of the study was nine weeks, in which the teaching and learning sessions were conducted for 7 weeks that involved the addition, subtraction as well as the concept of 'from' in fractions, which is equivalent to multiplication of fractions, after the pre-test was administered to both groups. The post-test was administered in week nine after the completion of the teaching and learning session.

Instruments

The instruments for this study consisted of a pre-test and a post-test. The items developed in both instruments were based on the Year Five Mathematics Curriculum and Assessment Standard Document (DSKP) and textbook which covered the topics of addition, subtraction and the concept of 'from' in fractions. Both these instruments contained 15 subjective items that tested pupils' fractional problem-solving abilities. Similar items were used in both instruments which differed only in the numbering arrangements of items in the post-test. The pre-test was

administered to the samples prior to the treatment. The post-test was administered to measure the effect of the treatment, i.e. whether there was any improvement in the findings. Four Mathematics experts were consulted for the purpose of reviewing both instruments. Expert review is necessary to ensure the accuracy and clarity of the content of the tests to be administered (Kline, 2005).

Research procedure

The study was carried out for nine weeks, of which the teaching and learning sessions were conducted for seven weeks. Prior to the study, training regarding the administration procedures for the pre-test and post-test as well as on how to utilize Minecraft in the teaching and learning of fractions was conducted for two weeks in five sessions with the Mathematics teacher who will be involved in carrying out the lessons. Upon completion of the training, the pre-test was administered to both groups. This was followed by the teaching and learning of fractions from week two until week eight. In the treatment group, the teaching and learning of fractions involved carrying out fractional problem-solving activities in several Minecraft worlds in which the activities were created. The post-test was administered to both groups in week nine after the lessons were completed. Table 3 shows a list of Minecraft worlds that contain the activities.

Table 3: List of Minecraft worlds and the descriptions of the related fractional problem-solving activities

Minecraft World	Descriptions
Introduction to fraction model	A world where fractions are shown in the form of a model through the manipulation of blocks.
Proper fractions	A world where examples of proper fractions are shown through the manipulation of blocks.
Improper fractions	A world where examples of improper fractions are shown through the manipulation of blocks.
Equivalent fractions	A world where examples of equivalent fractions are shown through the manipulation of blocks.
Mixed fractions	A world where examples of mixed fractions are shown through the manipulation of blocks.
Addition of fractions	A world that shows how fractions are added. The addition of fractions includes proper fractions, improper fractions and mixed fractions.
Subtraction of fractions	A world that shows how fractions are subtracted. The subtraction of fractions includes proper fractions, improper fractions and mixed fractions.
Multiplication of fractions	A world that shows how fractions are multiplied. The multiplication of fractions includes proper fractions, improper fractions and mixed fractions.
Hands-on with addition of fractions	A world where pupils perform problem-solving activities involving the addition of fractions through the manipulation of blocks.
Hands-on with subtraction of fractions	A world where pupils perform problem-solving activities involving the subtraction of fractions through the manipulation of blocks.
Hands-on with multiplication of fractions	A world where pupils perform problem-solving activities involving the multiplication of fractions through the manipulation of blocks.

FINDINGS

Data were analysed using SPSS. Results of the analysis are shown as follows:

Hypothesis $H_0$1: There is no significant difference between the pre-test and post-test achievement score mean for the topic of fractions in the control group

Paired samples t-test was performed for the control group to identify the difference between the pre-test and post-test achievement score mean. Based on table 7, p = .18 is greater than the significant value of .05. Therefore, there is no significant difference between the pre-test and post-test achievement score mean in the control group (t(33) = -1.35, p = .18). The null hypothesis fails to be rejected.

Table 7: Comparison of pre-test and post-test achievement score means of the control group

Marks	N	Mean	Standard deviation	Mean difference	t	df	*P*
Pre-test Post-test	34	6.02 6.20	2.75 2.79	-.17	-1.35	33	.18

*significant $p < 0.05$

Hypothesis $H_0$2: There is no significant difference between the pre-test and post-test achievement score mean for the topic of fractions in the treatment group

Paired samples t-test was performed for the treatment group to identify the difference between the pre-test and post-test achievement score mean. Based on table 8, p = .00 is less than the significant value of .05. Therefore, there is a significant difference between the pre-test and post-test achievement score mean in the treatment group (t(30) = -4.04, p = .00). The null hypothesis is rejected.

Table 8: Comparison of pre-test and post-test achievement score means of the treatment group

Marks	N	Mean	Standard deviation	Mean difference	t	df	*p*
Pre-test Post-test	31	6.93 8.80	3.15 2.77	-1.87	-4.04	30	.00

*significant $p < 0.05$

Hypothesis $H_0$3: There is no significant difference in the post-test achievement score mean for the topic of fractions between the control group and the treatment group

Table 9 shows the statistics of the post-test achievement score mean for the control group and treatment group.

Table 9: Statistics of the post-test achievement score mean for the control group and treatment group

Marks	Group	N	Mean	Standard deviation	Standard error of the mean
Post-test	Control	34	6.20	2.79	3.11
	Treatment	31	8.80	2.77	3.09

Based on Table 10, Levene's test for the equality of variances which is not significant (p = .78 > .05) showed that both the control and treatment groups have similar variances. This means that the null hypothesis which states that the variance for the control group is equal to the variance for the treatment group fails to be rejected. Thus, the comparisons of the mean of two groups of independent samples that have the same variance are considered (equal variances assumed). Since the probability value obtained (.00) is less than the value of significance (.05), the null hypothesis is rejected. There is a significant difference between the post-test achievement score mean for the control group (M = 6.20, SD = 2.79 and the post-test achievement score mean for the treatment group (M = 8.80, SD = 2.77) for the topic of fractions. The treatment group obtained a higher mean compared to the control group.

Table 10: Statistics of the post-test achievement score mean for the control group and treatment groups

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Post-test marks	Equal variances assumed	0.07	0.78	-3.6	63	0.00	-15.86	4.4	-24.66	-7.06
	Equal variances not assumed			-3.61	62.89	0.00	-15.86	4.39	-24.64	-7.08

*significant $p < 0.05$

DISCUSSION

The findings of the study indicated that the use of Minecraft in the teaching and learning of fractions had helped improve pupils' achievement compared to the use of conventional methods. Minecraft provides a platform for pupils to perform manipulations on virtual blocks when carrying out fractional problem-solving activities which at the same time provides entertainment as well as encourages the active involvement of pupils in the learning process. The element of entertainment that was brought forth by Minecraft had made learning more fun and enjoyable. This has led to pupils being more attentive and highly motivated during lessons in line with the study by Hwang et al., (2015), Yang (2015) and Wang et al., (2011).

As a technology that features heavily on graphical display, Minecraft used in DGBL has improved the conceptual understanding and mastery of fractions among the pupils and has been applied in performing fractional problem-solving. Based on the study, the use of Minecraft has helped pupils to effectively visualize the concepts of fractions. They are able to visualize the concepts of fractions easily and effectively since Minecraft allows them to perform hands-on fractional problem-solving activities through the manipulation of blocks. This is in line with the findings of Kim and Park (2018) that discover that the implementation of mathematical activities using Minecraft has improved the effectiveness of the teaching and learning of Mathematics by helping pupils to better visualize mathematical concepts in a virtual environment. Pupils can arrange, move, destroy and modify blocks in Minecraft to form fraction models and then perform fractional problem-solving through the manipulation of the blocks. Piaget (1965) had stated that pupils would often have difficulties in understanding and learning abstract mathematical concepts when presented either in words or symbols through direct explanation. This is because the pupils have not reached the cognitive maturity required to understand such abstract mathematical concepts. Thus, he argued that the pupils would be able to learn abstract mathematical concepts better and more effectively as a result of their experience of interacting with or manipulating objects as well as concrete materials. Minecraft allows pupils to visually see and interact with the blocks when carrying out fraction problem solving activities. The ability to visualize concepts of fractions well will assist in forming a strong conceptual understanding of fractions (Abdul Halim et al., 2015; Özkan et al., 2018). Hands-on manipulation activities in Minecraft helps to establish a connection between the manipulation activities and abstract mathematical concepts because when their mathematical abilities improve as a result of performing the activities, they will have a better understanding of

mathematical concepts and be able to visualize those concepts better in their minds (Holmes, 2013; Kontaş, 2016). Manipulation activities allow pupils to integrate knowledge and relate it to their thinking in order to understand mathematical concepts more comprehensively (Boggan et al., 2010; Kelly, 2006) and this contributes to the pupils' ability to solve problems involving fractions which will result in improvement in their achievements.

DGBL using Minecraft also encourage the active participation of pupils during lessons as a result of the student-centered learning nature of this learning method. Pupils will be actively involved in carrying out problem-solving activities in Minecraft since digital games are able to create interactive learning experiences by converting inactive learning materials to learning materials where students are the active players and participants (Sugar & Takacs, 1999). The active participation of pupils as a result of the use of DGBL is also due to the nature of digital games which provide a responsive environment where pupils are immediately aware of what they are doing and what is happening in the digital game (Cruickshank & Telfer, 1980). This will sustain the involvement and interest of pupils to follow lessons and the more they are actively and comprehensively involved in the teaching and learning, the more skills and knowledge they will acquire. These skills and knowledge will assist in solving problems related to fractions, thus improving their achievement in the topic.

IMPLICATION OF STUDY

The use of Minecraft especially in the teaching and learning of fractions has the potential to contribute to the creation of a virtual learning environment that is able to provide an interactive, dynamic, fun and enjoyable learning experience which in turn will make pupils more engaged and focused during lessons. Being able to gain the pupils' attention and interest in the lesson will greatly improve their learning and enable them to attain a proper understanding regarding the concepts of fractions. In addition, DGBL is able to improve the pupils' achievement in fractions, hence highlighting the need for teachers to receive guidance and training on techniques of implementing DGBL, especially in regard to integrating digital games into the teaching and learning sessions.

CONCLUSION

This study has shown that the use of Minecraft in the teaching and learning of fractions has a positive impact on pupils' achievement in fractions. The ability of pupils to solve problems involving fractions will help to achieve the aspirations of the Mathematics curriculum in Malaysia as well as further improve Malaysia's performance in international assessments such as TIMSS and PISA. Therefore, educators need to take the initiative to use DGBL considering the potential of this method in supporting and improving learning, especially in academic performance and achievement.

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