Anatolian Journal of Education
e-ISSN: 2547-9652

October 2023 ● Vol.8, No.2
www.e-aje.net
pp. 1-20

The Effect of Minecraft on Learners' Higher-Order Thinking Skills in Fractional Problem-Solving

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This study aims to investigate the effect of using Minecraft on Year 5 pupils' higher-order thinking skills (HOTS) in fractional problems-solving. A quasi-experimental pretest and posttest non-equivalent groups design was used. The study sample involved 65 Year 5 pupils from two intact classes which consists of 31 pupils as the treatment group and the other 34 pupils as the control group. Minecraft was used as the intervention in the teaching and learning of fractions in the treatment group. The research data was collected through the administration of pretest and posttest while the data was analyzed using paired sample t-test and independent sample t-test. The research resulted in several findings. Among them is the significant difference in the ability to solve fractional problems which requires the use of HOTS between pupils who were exposed to the teaching and learning of fractions using Minecraft and pupils who were exposed to the teaching and learning of fractions using conventional methods. This study has proven that the use of Minecraft in the teaching and learning of fractions has the potential to facilitate and enhance pupils' level of HOTS.

Keywords: higher-order thinking skills (HOTS), fractions, Minecraft, digital learning, problem-solving

INTRODUCTION

In preparing pupils to face the challenges of the Industrial Revolution 4.0, there is a need for educators to innovate the teaching and learning process (Dewantara et al., 2019; Dewantara et al., 2020). Among the reason for this necessity is to equip pupils with 21st century skills which would enable them to compete and be competitive in today's globalized era. According to Ghavifekr and Rosdy (2015), Hartini et al. (2017), Sudarsono et al. (2022) and Tangkui and Keong (2020), among the strategies that can be applied to innovate teaching and learning is the integration of technology in the daily classroom instructional process. Technology plays a significant role in helping teachers deliver lessons and students in learning which in turn offers diverse opportunities for both teachers and students to support the teaching and learning processes (Castillo-Manzano et al., 2016; Janssen & Bodemer, 2013). With the rapid advancement of Information and Communication Technology (ICT), the integration of ICT in education has become vital to create a technology-based teaching and learning environment which would lead to effective learning (Jamieson-Procter et al., 2013), especially in stimulating and improving students' understanding of a particular subject (Ghavifekr & Rosdy, 2015), provides a variety of constructive learning activities (Sailer et al., 2021) as well as improving students' learning outcomes (Hariadi et al., 2022). The teaching and learning of mathematics can be more effective with ICT integration, given the presence of technology-based tools are able to support active learning (Jorge et al., 2003), thus making teaching and learning more effective and exciting (Amutha, 2020). Learning mathematics involves mastering basic concepts and skills and developing problem-solving skills, which require thinking skills (Li et al., 2020). Therefore, the integration of ICT in education has

Citation: Tangkui, R. B., & Keong, T. C. (2023). The effect of Minecraft on learners' higher-order thinking skills in fractional problem-solving. *Anatolian Journal of Education*, *8*(2), 1-20. https://doi.org/10.29333/aje.2023.821a

become a new norm of teaching and learning, particularly involving digital games. Digital games are increasingly integrated into the teaching and learning process to increase and promote student learning, achievement, and development and at the same time cultivate 21st century skills such as higher-order thinking skills (HOTS).

The ability to solve problems, especially problems involving real-world situations, has become a necessity in the 21st century as these problems have become more complex and complicated. According to Ichsan et al. (2019), problem-solving is an activity that can generate and develop HOTS. HOTS are cognitive processes that involve thinking at a more complex and higher level (Anderson & Krathwohl, 2001) which comprises critical thinking, logical thinking, reflective thinking, creative thinking, metacognition, decision making, and problem-solving (King et al., 2018; Marshall & Horton, 2011; Widodo & Kadarwati, 2013). Students need to have a good grasp of HOTS because in real world situations, they will encounter many complex and complicated problems that require higher-order thinking in order to solve those problems. By having this skill, they will be able to process and analyze information critically and solve problems creatively using the information and knowledge at hand and thus make decisions in complex situations (Saputra, 2016).

The need to implement HOTS in mathematics curriculum should be emphasized, especially in the teaching and learning of fractions. In Malaysia, the teaching and learning of fractions have been implemented starting from primary level. This is because school children, particularly pupils, need to have a solid conceptual understanding of fractions from an early age. Fractions are complex yet one of the essential concepts in mathematics. Having a solid conceptual understanding of fractions is necessary to provide a solid foundation for the formation and development of mathematical ideas (Zakiah et al., 2013) and assist in the mastery of other more complex mathematical concepts such as algebra (Booth et al., 2014). Furthermore, the importance of fractions is evident in that it is used extensively in measurements and calculation such as percentages, ratios, rates and decimals (Abdul Halim et al., 2015; Booth et al., 2014; Ndalichako, 2013; Van de Walle et al., 2013; Wijaya, 2017).

However, low achievement in mathematics especially in the Trends in Mathematics and Science Studies (TIMSS) international assessment showed that many Malaysian students are having difficulties in learning and mastering the topic, thus indicating that these students have not yet achieved a satisfactory level of mastery of HOTS (Abdul Halim et al., 2015; Mullis et al., 2008; Mullis et al., 2012; Mullis et al., 2016; Mullis et al. 2020; Nor'ain & Mohan Chinnappan, 2016). *Based on the TIMSS assessment framework, 15% of the items tested under the Numbers domain involve fractions.* The inability to achieve a satisfactory level of higher-order thinking has caused Malaysian students to experience difficulties in solving mathematical problems in the assessment. These difficulties are due to the questions or items in the assessment involve problem-solving that contain elements of HOTS (Abdul Halim et al., 2015; Dossey et al., 2007; Mullis et al., 2008; Mullis et al. et al., 2012; Mullis et al., 2016; Mullis et al., 2020). Analysis of achievements in TIMSS from 1999 to 2019 in Table 1 shows that Malaysia's achievements in mathematics are showing a declining trend. Malaysia's average scores in TIMSS 2007 until TIMSS 2019 were well below the international average score of 500 based on the TIMSS global benchmarks of mathematics achievement shown in Table 2. Among the reasons that contributed to this decline and Malaysian students' difficulty in mastering HOTS were the students' inability to fully grasp the conceptual understanding of fractions which was caused by whole number bias (Azizan & Ibrahim, 2012; Braithwaite & Siegler, 2017; DeWolf & Vosniadou, 2015; Ni & Zhou, 2005) where students incorrectly apply whole number concepts to fractions (DeWolf & Vosniadou, 2015; Siegler et al., 2012; Vamvakoussi & Vosniadou, 2010) particularly performing arithmetic operations on numerators and denominators separately as if they were independent whole numbers (Braithwaite et al., 2017; Braithwaite et al., 2021; Gabriel et al., 2013; Siegler et al., 2011, Van Steenbrugge et al., 2014). Students' prior exposure to the concept of whole numbers may have affected their conceptual understanding of fractions and fraction-related operations (Olkun & Toluk-

Ucar, 2012; Ünlü & Ertekin, 2012), thus affecting their ability to solve fractional problems correctly (Mokhtar et al., 2019), especially fractional problems which involve the use of HOTS. Therefore, based on the achievements in the international assessment, there is an urgent need to improve, increase and facilitate Malaysian students' ability and mastery of HOTS, particularly in solving problems regarding fractions. Based on these achievements, there is an urgent need to improve, increase and facilitate Malaysian students' ability and mastery of HOTS in solving fractional problems.

Table 1
Malaysia's achievements and positions in mathematics in TIMSS 1999-2019

Year	Average score	Position
1995	1999 Did not participate	45 countries participated
1999	519	16 out of 38 participating countries
2003	508	10 out of 49 participating countries
2007	474	20 out of 59 participating countries
2011	440	26 out of 63 participating countries
2015	465	22 out of 57 participating countries
2019	461	26 out of 36 participating countries

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

Thus, by acknowledging ICT's ability to the effectiveness of teaching and learning, the use of digital games in teaching and learning is seen as an approach that needs to be implemented to improve Year 5 pupils' HOTS in solving fractional problems. *Digital games have been applied in educational settings to determine its effect on several variables such as engagement (Annetta et al., 2010), motivation (Murat Turgut & Onur Mutlu Yasar, 2019), academic achievement (Chen, 2017; Siew et al., 2016; Yeh et al., 2017) and learning experience (Panja & Berge, 2021). However, empirical findings regarding the effect of digital games, particularly Minecraft, on pupils' HOTS in solving fractional problems needs to be further explored. Therefore, the purpose of this study includes: (1) to determine the difference in the mean achievement score for the HOTS of analysing between pupils who were exposed to the teaching and learning of fractions using Minecraft and pupils who were taught using conventional methods, (2) to determine the difference in the mean achievement score for the HOTS of evaluating between pupils who were exposed to the teaching and learning of fractions using Minecraft and pupils who were taught using conventional methods and (3) to determine the difference in the mean achievement score for the HOTS of creating between pupils who were exposed to the teaching and learning of fractions using Minecraft and pupils who were taught using conventional methods with the following research hypothesis:*

$H_0$1: There is no significant difference between the pretest and posttest mean achievement score in the control group for the HOTS of analyzing

$H_0$2: There is no significant difference between the pretest and posttest mean achievement score in the control group for the HOTS of evaluating

$H_0$3: There is no significant difference between the pretest and posttest mean achievement score in the control group for the HOTS of creating

$H_0$4: There is no significant difference between the pretest and posttest mean achievement score in the treatment group for the HOTS of analyzing

$H_0$5: There is no significant difference between the pretest and posttest mean achievement score in the treatment group for the HOTS of evaluating
$H_0$6: There is no significant difference between the pretest and posttest mean achievement score in the treatment group for the HOTS of creating
$H_0$7: There is no significant difference in the posttest mean achievement score between the control group and the treatment group for the HOTS of analyzing
$H_0$8: There is no significant difference in the posttest mean achievement score between the control group and the treatment group for the HOTS of evaluating
$H_0$9: There is no significant difference in the posttest mean achievement score between the control group and the treatment group for the HOTS of creating

Literature Review

Minecraft

Minecraft is an ‘open-world’ digital game with a 'sandbox' concept. The term ‘open-world’ is used to describe a game mechanic that offers a virtual world for players to explore (Sefton, 2008). Furthermore, 'sandbox' digital games are games that do not set specific objectives to be achieved and give players the freedom to explore, interact and adapt to the environment of the virtual world of the digital game (Kuhn & Stevens, 2017). With that said, Minecraft is a digital game that allows players to explore, interact and manipulate virtual objects and materials in a virtual world without a clear ending and without any objectives that need to be achieved (Donellan, 2019). Players will use various materials in Minecraft, especially 3D blocks, to build concrete objects according to the player's imagination and this is done by collecting, breaking, reconstructing, removing and placing the blocks randomly in Minecraft (Bos et al., 2014; Ekaputra et al., 2013; Kim & Park, 2018; Lane et al., 2017; Mojang, 2015a; Nebel et al., 2016).

Learning Fractions Using Minecraft

The existence of the whole number misconception shows that students are having difficulties in understanding and mastering the concepts of fractions (Simon et al., 2018; Zakiah et al., 2013). In addition, students' inability to visualize fractions abstractly in their minds also affected them in understanding and mastering the concept. The use of Minecraft has the potential to strengthen understanding and mastery of the concepts of fractions as the digital game allows the implementation of hands-on activities, especially activities that involve solving fractions problems. 3D blocks in the virtual world of Minecraft can be manipulated to form concrete objects to represent fractions which are called fraction models. By using fraction models, students will be able to visualize the value of a fraction more clearly and easily in their minds.

According to Holmes (2013) and Kontaş (2016), carrying out hands-on activities will help to establish a relationship between the activities with mathematical concepts because through hands-on activities, students will be able to understand abstract mathematical concepts better as they are able to visualize the mathematical concepts better and clear in their mind. Besides that, carrying out hands-on activities will also assist in developing increasingly complex knowledge (Bruner, 1977; Dienes, 1973; Piaget, 1965). Figure 1 shows a fraction model constructed in Minecraft to represent the fraction value of 2/3.

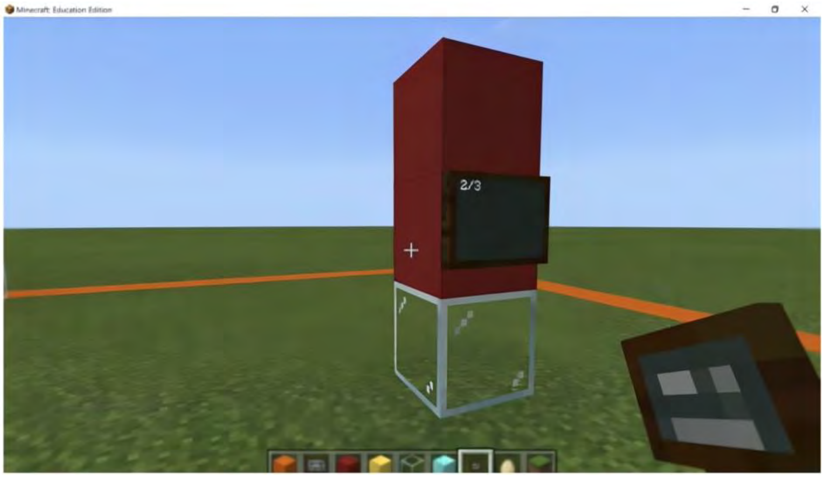

Figure 1
Fraction model with the value of 2/3

Higher-Order Thinking Skills (HOTS)

The Malaysian Ministry of Education (2013) has identified thinking skills as one of the key characteristics required by every student to compete globally. In facing the demands and challenges of today, students need to have the ability to think critically and solve problems, both of which are elements of HOTS (Kiener et al., 2014). Bereiter and Scardamalia (1987) stated that HOTS could be increased among students by designing and implementing instructional strategies that encourage critical thinking and problem-solving approaches. According to Thomas and Thorne (2009), HOTS can be learned and developed. Therefore, in designing and implementing instructional strategies to increase HOTS among students, a reference must be made to Bloom's Taxonomy.

Bloom's Taxonomy refers to a classification system that aims to classify learning goals and objectives into three learning domains: cognitive, affective, and psychomotor based on different levels of thinking, ranging from low-level to high-level thinking (Bloom et al., 1956). The idea behind this taxonomy is that what teachers want students to know (based on learning objectives) can be arranged in a hierarchy ranging from simple levels to more complex levels. In the cognitive domain, Bloom et al. (1956) identified six levels of cognitive processes that are becoming increasingly complex and challenging. The six levels are knowledge, understanding, application, analysis, synthesis, and evaluation, with analysis, synthesis and evaluation being the higher-order cognitive processes. According to Adams (2015), Bloom's Taxonomy calls attention to learning objectives requiring higher cognitive skills, leading to deeper learning and transfer of knowledge and skills to various tasks and contexts.

Bloom's Taxonomy has been revised and several improvements have been made to the original taxonomy. Changes and improvements were made to the original Bloom's Taxonomy to illustrate that thinking is an active process and to ensure that the taxonomy is relevant to the current academic demands and challenges (Anderson and Krathwohl (2001). Changes were made to the names of the six levels of thinking in the original taxonomy, namely from nouns to verbs. The use of verbs is more appropriate given the characteristics of verbs that describe actions. The six levels of thinking in the Revised Bloom's Taxonomy are remembering, understanding, applying, analyzing, evaluating and creating. The top three cognitive processes of analyzing, evaluating and creating are classified as HOTS (Anderson & Krathwohl, 2001). Based on the Revised Bloom's Taxonomy, the HOTS of analyzing can be defined as breaking down information into small parts to understand the information better and determine how the parts relate to each other. The HOTS of evaluating can be defined as making judgments and decisions using knowledge, values and skills by providing justifications while the HOTS of creating can be defined as generating new ideas, methods or products based on knowledge gained (Anderson & Krathwohl, 2001).

Integrating HOTS in the Teaching and Learning of Fractions using Minecraft

It is possible to integrate HOTS into the teaching and learning of fractions particularly through digital game-based learning by referring and applying the concepts of Bloom's Revised Taxonomy. The Bloom's Revised Taxonomy would act as a reference and guide in the planning, designing and development of activities and assessment items that involve elements of HOTS as well as in assessing students' learning based on the elements of HOTS (Bahagian Pembangunan Kurikulum, 2014; Zollman, 2012). One of the main reasons for referring to the Bloom's Revised Taxonomy is that the taxonomy describes in detail the increasing stages of thinking, where the level of thinking in each stage is describe using verbs which are categorized according to the different levels of thinking. Therefore, reference to the verbs in the taxonomy allows teachers to plan, design develop and construct activities as well as assessment items to achieve the intended learning objectives. Table 3 shows examples of verbs that have been categorized according to the HOTS of analysing, evaluating and creating based on the Bloom's Revised Taxonomy which can be referred to for the purpose of planning, designing, developing and constructing digital game-based learning activities and assessment items.

Table 3
List of verbs based on levels of thinking in Bloom's Revised Taxonomy

Level of Thinking	Description	Verbs
Analyzing	Breaking information into smaller parts to explore understandings and relationships	Contrasting Comparing Deconstructing Organizing Interrogating
Evaluating	Justifying a decision or course of action	Critiquing Judging Experimenting Checking Hypothesizing
Creating	Generating new ideas, products or ways of viewing things	Designing Constructing Planning Producing Inventing

Source: Anderson & Krathwohl (2012)

METHOD

Research design and study sample

A quasi-experimental pretest-posttest nonequivalent groups design was used in this study. Quasi-experimental design was chosen for this study based on the following criteria: *(i) the administrative constraints of the selected primary school that did not allow the study sample to be randomly distributed, (ii) complex human behavior that made it unrealistic to conduct a true experimental study (iii) quasi-experimental design is able to identify the effect of an intervention or treatment on the study sample without affecting the course of the educational environment (Bryman, 2001; Pelham & Blanton, 2007), (iv) the use of existing classes (intact classes) in the design the quasi-experimental* *form is able to reduce the Hawthorne effect that usually occurs when samples are randomly distributed (Abdullah, 2018; Chong, 2003)*

The study sample consisted of 65 Year Five pupils from two intact classes of a primary school in the district of Kuala Penyu, Sabah, Malaysia. In line with the aim of this study, the selection of Year 5 pupils as the study samples in this study was based on the following criteria: i) Year 5 pupils were formally exposed to the basic knowledge and skills of fractions which has elements of HOTS while they were in Year 4, ii) the selection of Year 5 pupils met the criteria of the international assessment of TIMSS and PISA which among others stated that the study samples need to be of the age of 11 years old and iii) Year 5 pupils are 11 years of age which sets them in the concrete operational stage based on Piaget's theory of cognitive development. Operational concrete stage occurs when a child is between the ages of 7 and 11 years. During this stage, a child would start to display logical thinking, able to use deductive reasoning and is able to display understanding of abstract ideas (Scott & Cogburn, 2020; Viarouge et al., 2019) all of which are elements of HOTS. Through cluster sampling, the class which consists of 31 pupils was selected as the treatment group while the class which consists of 34 pupils was selected as the control group.

Minecraft was used in the teaching and learning of fractions in the treatment group while conventional methods were used in the control group. The duration of the study was nine weeks in which the teaching and learning of fractions were carried out for seven weeks starting from week two to week eight. *Pretest was administered in week one while posttest was administered in week nine.*

Research Instruments

A pretest and posttest were used as research instruments. Both instruments contain 15 limited response items developed based on the Malaysian Year 5 Mathematics Curriculum and Assessment Standard Document and textbook which would test the pupils' fractional problem-solving abilities. Solving the items requires the use of high-level thinking; 8 items require pupils to use the HOTS of analyzing, 5 items require pupils to use the HOTS of evaluating while 2 items require pupils to use the HOTS of creating. The same items were used in both instruments with the only difference being the arrangement of the items in the posttest. For the pretest and posttest, items 1(a), 1(b), 2, 3, 4, 5, 6(a) and 6(b) would test the HOTS of analyzing, items 7, 8, 9, 10(a) and 10(b) would test the HOTS of evaluating while items 11 and 12 would test the HOTS of creating. The only difference between the pretest and posttest are the arrangement of items for each level of HOTS.

Instruments' Validity and Reliability

To improve the validity of the instruments, face validity, content and construct validity were carried out. Four experts in mathematics were consulted to review the instruments for face and content validity. As for construct validity, reference was made to the Revised Bloom's Taxonomy.

The reliability values of the instruments were determined based on inter-rater reliability, which is the degree or level of agreement between raters, with reference made to the Cohen Kappa values. Two primary school mathematics teachers were enlisted as raters. Marks given by both teachers for each item in the pretest were analyzed and interpreted based on Cohen Kappa's level of agreement value. Table 4 shows the interpretation of the level of agreement between raters based on the value of Cohen Kappa (McHugh, 2012) while Table 5 shows the inter-rater reliability for the pretest items.

Table 4
Cohen Kappa value interpretation

Cohen Kappa Value	Level of Agreement
0 - .20	None
.21 - .39	Minimal
.40 - .59	Weak
.60 - .79	Moderate
.80 - .90	Strong
Above .90	Almost perfect

Source: McHugh (2012)

Table 5
Inter-rater reliability for pretest items

Item	Cohen Kappa Value	Level of agreement
1(a)	0.932	Almost perfect
1(b)	0.948	Almost perfect
2	0.950	Almost perfect
3	0.895	Strong
4	0.895	Strong
5	0.944	Almost perfect
6(a)	0.862	Strong
6(b)	0.927	Almost perfect
7	0.938	Almost perfect
8	1.000	Almost perfect
9	0.925	Almost perfect
10(a)	0.918	Almost perfect
10(b)	1.000	Almost perfect
11	0.907	Almost perfect
12	0.912	Almost perfect

Statistical Analysis

Data analysis involved using paired samples t-test to compare pretest mean achievement scores and posttest mean achievement scores within the treatment and control groups. In contrast, the independent samples t-test was used to compare the posttest mean achievement score between the treatment and control groups.

FINDINGS

H_01: There is no significant difference between the pretest and posttest mean achievement scores in the control group for the HOTS of analyzing

Based on Table 6, p = .18 is greater than the significance level of .05. Therefore, the null hypothesis fails to be rejected. There is no significant difference between the pretest and posttest mean achievement scores in the control group (t (33) = 1.36, p = .18) for the HOTS of analyzing. This indicates that pupils in the control group experienced a minimal improvement in achievement scores when exposed to conventional methods, which shows that conventional methods had minimal impact in enhancing the levels of the HOTS of analyzing.

Table 6
Comparison of pretest and posttest mean achievement scores of the control group for the HOTS of analyzing

	N	*Mean*	*Standard Deviation*	*Mean Difference*	*t*	*df*	*Sig. (2-tailed)*
Pretest score	*34*	6.03	2.76	-.176	-1.36	33	.18
Posttest score		6.20	2.79				

*Significant at $p < .05$

H₀2: There is no significant difference between the pretest and posttest mean achievement scores in the control group for the HOTS of evaluating

Based on Table 7, p = .09 is greater that the significance level of .05. Therefore, the null hypothesis fails to be rejected. There is no significant difference between the pretest and posttest mean achievement scores in the control group (t (33) = -1.71, p = .09) for the HOTS of evaluating. This indicates that pupils in the control group experienced a minimal improvement in achievement scores when exposed to conventional methods which shows that conventional methods had minimal impact in enhancing the levels of the HOTS of evaluating.

Table 7
Comparison of pretest and posttest mean achievement scores of the control group for the HOTS of evaluating

	N	*Mean*	*Standard Deviation*	*Mean Difference*	*t*	*df*	*Sig. (2-tailed)*
Pretest score	*34*	*2.50*	1.48	-.14	-1.71	33	.09
Posttest score		2.67	1.59				

*Significant at $p < .05$

H₀3: There is no significant difference between the pretest and posttest mean achievement scores in the control group for the HOTS of creating

Based on Table 8, p = .16 is greater that the significance level of .05. Therefore, the null hypothesis fails to be rejected. There is no significant difference between the pretest and posttest mean achievement scores in the control group (t (33) = -1.43, p = .16) for the HOTS of creating. This indicates that pupils in the control group experienced a minimal improvement in achievement scores when exposed to conventional methods, which shows that conventional methods had minimal impact in enhancing the levels of the HOTS of creating.

Table 8
Comparison of pretest and posttest mean achievement scores of the control group for the HOTS of creating

	N	*Mean*	*Standard Deviation*	*Mean Difference*	*t*	*df*	*Sig. (2-tailed)*
Pretest score	*34*	*.41*	.70	-.05	-1.43	33	.16
Posttest score		.47	.74				

*Significant at $p < .05$

H₀4: There is no significant difference between the pretest and posttest mean achievement scores in the treatment group for the HOTS of analyzing

Based on Table 9, p = .00 is lower that the significance level of .05. Therefore, the null hypothesis is rejected. There is a significant difference between the pretest and posttest mean achievement scores in the treatment group (t (30) = -4.04, p = .00) for the HOTS of analyzing. This indicates that pupils in the treatment group experienced better achievement scores when exposed to the use of Minecraft in the teaching and learning of fractions, which also shows that the use of Minecraft is capable of enhancing the levels of the HOTS of analyzing.

Table 9
Comparison of pretest and posttest mean achievement scores of the treatment group for the HOTS of analyzing

	N	*Mean*	*Standard Deviation*	*Mean Difference*	*t*	*df*	*Sig. (2-tailed)*
Pretest score	*31*	*6.94*	3.15	-1.87	-4.04	33	.00
Posttest score		8.80	2.77				

** Significant at p < .05*

$H_0$5: There is no significant difference between the pretest and posttest mean achievement scores in the treatment group for the HOTS of evaluating

Based on Table 10, p = .00 is lower that the significance level of .05. Therefore, the null hypothesis is rejected. There is a significant difference between the pretest and posttest mean achievement scores in the treatment group (t (30) = 8.11, p = .00) for the HOTS of evaluating. This indicates that pupils in the treatment group experienced better achievement scores when exposed to the use of Minecraft in the teaching and learning of fractions, which also shows that the use of Minecraft is capable of enhancing the levels of the HOTS of evaluating.

Table 10
Comparison of pretest and posttest mean achievement scores of the treatment group for the HOTS of evaluating

	N	*Mean*	*Standard Deviation*	*Mean Difference*	*t*	*df*	*Sig. (2-tailed)*
Pretest score	*31*	*1.29*	1.32	2.25	8.11	30	.00
Posttest score		3.54	1.60				

** Significant at p < .05*

$H_0$6: There is no significant difference between the pretest and posttest mean achievement scores in the treatment group for the HOTS of creating

Based on Table 11, p = .00 is lower than the significance level of .05. Therefore, the null hypothesis is rejected. There is a significant difference between the pretest and posttest mean achievement scores in the treatment group (t (30) = -5.04, p = .00) for the HOTS of creating. This indicates that pupils in the treatment group experienced better achievement scores when exposed to the use of Minecraft in the teaching and learning of fractions, which also shows that the use of Minecraft can enhance the levels of the HOTS of creating.

Table 11
Comparison of pretest and posttest mean achievement scores of the treatment group for the HOTS of creating

	N	*Mean*	*Standard Deviation*	*Mean Difference*	*t*	*df*	*Sig. (2-tailed)*
Pretest score	*31*	*.38*	.55	-.67	-5.04	30	.00
Posttest score		1.06	.85				

** Significant at p < .05*

$H_0$7: There is no significant difference in the posttest mean achievement scores between the control group and the treatment group for the HOTS of analyzing

Table 12 shows the posttest mean achievement scores of the control group and the treatment group for the HOTS of analyzing.

Table 12
Posttest mean achievement scores of the control group and treatment group for the HOTS of analyzing

	Group	*N*	*Mean*	*Std. Deviation*	*Std. Error Mean*
Posttest score	*Control group*	*34*	*6.20*	*2.79*	*3.11*
	Treatment group	*31*	*8.80*	*2.77*	*3.09*

Based on Table 13, Levene's test for the equality of variances which is not significant (p = .78 > .05) showed that both the control group and treatment group have similar variances. Therefore, 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, so the result of the t-test with equal variances assumed is considered. As shown in Table 9, p = .00 is lower than the significance level of .05. Therefore, the null hypothesis is rejected. There is a significant difference in the posttest mean achievement scores between the control group and the treatment group (t (63) = -3.60, p = .00) for the HOTS of analyzing. The treatment group achieved higher mean achievement scores compared to the control group, thus indicating that pupils in the treatment group experienced better achievement scores when exposed to the use of Minecraft in the teaching and learning of fractions which also showed that their levels of HOTS of analyzing has been enhanced.

Table 13

Table 13
Independent samples test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Posttest Scores	Equal variances assumed	.07	.78	-3.60	63	.00	-15.86	4.40	4.40	-7.06
	Equal variances not assumed			-3.61	62.89	.00	-15.86	4.39	4.39	-7.08

*Significant at p < .05

$H_0$8: There is no significant difference in the posttest mean achievement scores between the control group and the treatment group for the HOTS of evaluating

Table 14 shows the posttest mean achievement scores of the control group and the treatment group for the HOTS of analyzing.

Table 14
Posttest mean achievement scores of the control group and treatment group for the HOTS of evaluating

	Group	N	Mean	Std. Deviation	Std. Error Mean
Posttest score	Control group	34	2.67	1.59	.27
	Treatment group	31	3.54	1.60	.28

Based on Table 15, Levene's test for the equality of variances which is not significant ($p = .94 > .05$) showed that both the control group and treatment group have similar variances. Therefore, 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, so the result of the t-test with equal variances assumed is considered. As shown in Table 12, $p = .03$ is lower than the significance level of .05. Therefore, the null hypothesis is rejected. There is a significant difference in the posttest mean achievement scores between the control group and the treatment group ($t (63) = -2.19$, $p = .03$) for the HOTS of evaluating. The treatment group achieved higher mean achievement scores compared to the control group, thus indicating that pupils in the treatment group experienced better achievement scores when exposed to the use of Minecraft in the teaching and learning of fractions which also showed that their levels of HOTS of evaluating has been enhanced.

Table 15
Independent samples test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Posttest Scores	Equal variances assumed	.006	.94	-2.19	63	.03	-.87	.39	-1.66	-.07
	Equal variances not assumed			-2.19	62.30	.03	-.87	.39	-1.66	-.07

**Significant at $p < .05$*

H_09: There is no significant difference in the posttest mean achievement scores between the control group and the treatment group for the HOTS of creating

Table 16 shows the posttest mean achievement scores of the control group and the treatment group for the HOTS of creating.

Table 16
Posttest mean achievement scores of the control group and treatment group for the HOTS of creating

	Group	N	Mean	Std. Deviation	Std. Error Mean
Posttest score	Control group	34	0.47	.74	.12
	Treatment group	31	1.06	.85	.15

Based on Table 17, Levene's test for the equality of variances which is not significant ($p = .94 > .05$) showed that both the control group and treatment group have similar variances. Therefore, 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, so the result of the t-test with equal variances assumed is considered. As shown in Table 14, $p = .00$ is lower than the significance level of .05. Therefore, the null hypothesis is rejected. There is a significant difference in the posttest mean achievement scores between the control group and the treatment group (t (63) = -2.98, p = .00) for the HOTS of creating. The treatment group achieved higher mean achievement scores compared to the control group, thus indicating that pupils in the treatment group experienced better achievement scores when exposed to the use of Minecraft in the teaching and learning of fractions which also showed that their levels of HOTS of creating has been enhanced.

Table 17
Independent samples test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Posttest Scores	Equal variances assumed	.08	.78	-2.98	63	.00	-.59	.19	-.99	-.19
	Equal variances not assumed			-2.97	59.98	.00	-.59	.19	-.99	-.19

**Significant at p < .05*

DISCUSSION

The objective of this study was to investigate the potential of using Minecraft in enhancing the levels of HOTS among Year 5 pupils in fractional problem-solving. The findings of this study have empirically proven that the use of Minecraft in the teaching and learning of fractions can enhance pupils' HOTS compared to using conventional methods. This is evident based on the improved achievement scores of pupils in the treatment group who were exposed to the teaching and learning of fractions using Minecraft.

Effects of Using Minecraft on the HOTS of Analyzing

Findings of the study indicated that the use of Minecraft in the teaching and learning of fractions has shown a positive effect on pupils' ability to solve fractional problems based on the posttest mean achievement score, thus proving that the use of digital games as an intervention in the teaching and learning process can enhance the level of the HOTS of analyzing.

Compared to conventional methods, the use of Minecraft in the teaching and learning process provides pupils with the opportunity to be actively involved in the lesson *particularly when carrying out activities that involve fractional problem-solving, with teachers playing more of a facilitator role.* By being actively involved in the teaching and learning process, pupils will be kept engaged in the lesson, thus providing them with the opportunity to interact more with what is being taught. This would enable them to learn more, store information longer and help reinforce knowledge, concepts and skills.

The study also showed that *the use of Minecraft has created a teaching and learning environment that is both fun and exciting, in line with the study by Nkadimeng and Ankiewicz (2022). The playful nature of the game, the presence of the elements of multimedia as well as being interactive at the same time, had contributed to the fun and exciting atmosphere of the teaching and learning session (Atler, 2017). This has proven to be effective in supporting pupils' learning as the use of digital games, particularly Minecraft, has sparked and generated pupils' interest towards the lesson being taught. When pupils are interested and are enjoying a lesson, they will tend to be more engaged and* *motivated towards that lesson which in turn will lead to effective memory processing and long-term memory storage (Kohn, 2004).*

Effects of Using Minecraft on the Level of HOTS of Evaluating

Minecraft provides a platform for pupils to perform hands-on fractional problem-solving activities through the manipulation of virtual blocks, and this has positively improved pupils' level of HOTS of evaluating. The ability to perform hands-on fractional problem-solving activities in Minecraft had enabled pupils to find solutions to a given fractional problem by manipulating fraction models. As pupils do not have restrictions and do not have to worry about making mistakes while performing hands-on activities in Minecraft, pupils are able to explore, reason and evaluate to find appropriate steps or solutions to solve a given a given problem. This process not only trains pupils to use high-level thinking to evaluate and solve problems but also improves pupils' problem-solving skills (Palmer, 2016). Furthermore, hands-on activities allow pupils to learn by experience, thereby providing them with a more realistic and exciting experience towards the content (Franklin & Peat, 2005; Noot & Wellington, 1996). Furthermore, the teaching and learning process which involves hands-on activities can generate pupils' curiosity, thus encouraging pupils to investigate and explore more about the activities (Kartono, 2010). As pupils spend more time interacting with and carrying out hands-on activities, particularly activities involving mathematics, pupils' understanding and knowledge of mathematical concepts can be further strengthened (Boggan et al., 2010; Kelly, 2006).

Effects of Using Minecraft Towards the Level of HOTS of Creating

Results of the analysis indicated that the use of Minecraft as an intervention in the teaching and learning of fractions has improved and enhanced the levels of the HOTS of creating among pupils in the treatment group. By referring to the Revised Bloom's Taxonomy, the HOTS of creating in this study focuses on the cognitive processes related to planning and constructing. Minecraft is a digital game that allows its players to build any structure through the manipulation of materials and elements withing the virtual world particularly virtual blocks (Bos et al., 2014; Ekaputra et al., 2013; 2016). In manipulating blocks to build structures, a player will usually start by planning. Planning in this sense involves choosing materials or tools that will be used to construct a structure, deciding on the shape and size of the structure, the location on which build the structure as well as for determining the components required to build the structure, for example in constructing a house, a player needs to plan and decide on the features that would make up the house such as doors, windows, roof and so on. The use of Minecraft in carrying out fractional problem-solving activities has enhanced the levels of the HOTS of creating among pupils since Minecraft enable pupils to plan structures that needed to be built and manipulated in order solve a particular problem in each activity. Findings of the study showed that the planning process involved pupils determining the steps or solutions to solve fractional problems in each activity by constructing manipulating structures in Minecraft which include constructing fractions models to illustrate ideas, information or concepts embedded in the activities. By being able to construct and manipulate structures in Minecraft, pupils will have a visual representation of the fractional problem which in turn will make it easier for pupils to have a better understanding of what is required to solve the problem. For example, in trying to solve a fractional problem which involves a house, pupils can start by planning on what resources are needed to build the house. The next step would be to plan on how to manipulate the house and the fraction models to come up with the appropriate solution to solve the problem. Therefore, through Minecraft, pupils will be provided with the ability to plan and construct, which are elements of the HOTS of creating, in order to generate new ideas or methods to solve those problems. Furthermore, the unique feature of Minecraft which allows flexibility in manipulating elements, materials as well as resources has enabled pupils to be creative in using their cognitive abilities to produce steps or solutions to a problem, where the ability to produce is among the characteristics of the HOTS of creating.

CONCLUSION

This study has proven that the use of Minecraft, when properly and systematically applied in the teaching and learning process, would be able to enhance pupils' level of HOTS which in turn will assist in solving problems related to fractions that require the use of high-level thinking. Pupils' ability to solve fractional problems which contains elements of HOTS will help achieve the aspirations of the mathematics curriculum in Malaysia and further Malaysia's achievements in international assessment. Therefore, educators need to take the initiative to innovate their teaching approaches by integrating digital games into the classroom as this method has the potential to support and improve learning.

Although this study has achieved its aim, it should be noted that there is still room for improvement. Therefore, some suggestions would be highlighted that would act as a reference for further studies. The recommendations are as follows:

(i) further studies should focus on the effects of Minecraft on HOTS between genders. This is to determine whether gender affects the findings of the research such as academic achievement, cognitive ability as well as creativity in line with the recommendations by Van Den Besselaar and Sandström (2016)

(ii) further studies should compare the effects of using Minecraft on HOTS between low-achieving pupils and high-achieving pupils

(iii) further studies should focus on the pedagogical aspects of the teaching and learning process which involves the use of digital games. The study needs to take into account the impact of using digital games on pedagogy and how it could contribute in making learning more effective

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