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Minecraft as a Tool for Digital Game-Based Learning: Enhancing Conceptual Understanding and Attitudes in Mathematics Learning

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Abstract: One of the teaching approaches most used to enhance mathematics learning by educators is digital game-based learning. With advancements in technology, many games have been integrated into educational methods. This research employed a quasi-experimental design investigated students' conceptual understanding and their attitude toward mathematics learning using Minecraft. In this study, the forty-five of third grade students from primary school in the northeastern region of Thailand were divided into two groups. The findings of the study indicate that the control group scored higher than the experimental group on the pre-test. However, after the intervention, the experimental group, which utilized Minecraft as an educational tool, demonstrated significant progress, showed significant improvement, effectively decreasing the performance gap between the two groups. Furthermore, the results demonstrate that Minecraft effectively fosters positive attitudes and enhances academic achievement in mathematics. Regarding the limitation, the relatively small sample size in both groups may limit the generalizability of the findings, indicating a need for future studies with larger samples.

Keywords: Minecraft, digital game-based learning, attitude, primary student

1. Introduction

The use of technology in education greatly improves learning quality in the tech-driven world of today by offering individualized and interactive experiences. For instance, Chang et al. (2022) explored VR-based learning in nursing education, finding it significantly improved problem-solving skills, engagement, and learning by linking theory with practical application in a realistic environment. Additionally, students who played video games online for more than two hours on weekends report higher math scores and increased happiness (Cano et al., 2022). Furthermore, integrating technology with teaching fosters engaging environments. For example, peer assessment in computer-supported collaborative inquiry learning (CSCiL) significantly improves students' inquiry results and perception of fairness (Hoe et al., 2024).

One approach often used by educators in educational research is digital game-based learning. Digital Game-Based Learning (DGBL) is also effective for enhancing student learning. Several games were used in DGBL such as Kahoot, SimCity Edu and Minecraft. Especially Minecraft widely used in education. For example, in mathematics, integrating Minecraft with game-based learning applications improves motivation and participation. It's crucial to consider how engaging educational experiences can positively influence students' attitudes toward mathematics (Kerszánszki et al., 2024). Similarly, Jensen and Hanghøj (2019) found that engaging with Minecraft's coordinate system enhances mathematical understanding and fosters new ways of participating in mathematics. However, the difficulty of the mathematics content, such as fractions and multiplication, can cause boredom.

According to the study of Schiebe et al. (2024) noted that maybe because of students' previous experience in the classroom when they faced to formal context in math can make students trigger feelings of fear or boredom.

Given the benefits of Minecraft toward learning mathematics, this study aims to enhance students' conceptual understanding of math, particularly multiplication, and promote their attitudes by using Minecraft as an engaging educational tool.

2. Literature Review

2.1 Serious Game and Mathematics Learning

Serious games are digital tools designed for educational purposes, blending learning with entertainment. They provide interactive experiences that engage students across various subjects. For example, Nurhayati and Alif (2023) propose Math-VR, a serious game incorporating virtual reality and ambient intelligence for enhancing mathematics learning, showing promising results in improving students' understanding of mathematical concepts. Ahmad and Junaini (2022) illustrate the potential of serious games in teaching geometry with prismAR, a mobile AR game for primary students. Their findings indicate that prismAR was well-received and contributed to students' understanding of prisms. This supports the growing body of research suggesting that when well-designed, serious games can effectively enhance learning outcomes and promote deeper engagement with challenging subjects.

2.2 Minecraft in Education

Minecraft lets users create and explore virtual worlds composed of textured cubes, which improves resource management and creativity. With the release of the creative and survival modes in 2011, it has offered a flexible platform for both single-player and multiplayer games. Additionally, the game's extensive modding community and educational adaptations further highlight its versatility as a learning tool. Numerous educators have sought to integrate Minecraft with academic content by leveraging its features. For instance, the study by Bile (2022) found that using Minecraft in educational settings enhances students' academic performance and deepens their understanding of scientific concepts. Moreover, research in Ireland indicates that the combination of Minecraft with project-based learning fosters essential 21st-century skills while providing a comprehensive learning experience (Slatter et al., 2023). Furthermore, although playing Minecraft alone may not significantly enhance mathematics education, utilizing the game to create meaningful mathematical practices increases student engagement and enjoyment (Jensen & Hanghøj, 2019).

3. Research Methodology

3.1 Participants

The participants in this study were third-grade students from a university-based primary school in the northeast region of Thailand. A total of forty-five students from two classes were involved in the experiment. Twenty-three students are in the experimental group. Twenty-two students are in the control group. The selection of students was not based on random sampling; instead, the study utilized the classes that were present. The participants have prior experience in using technology in mathematics learning.

3.2 Research Instruments

This research used two instruments to collect the data of students' understanding of multiplication concepts and their attitudes of learning through Minecraft. The first instrument is an attitude questionnaire regarding the use of technology to learn mathematics that adapted

from the study of Pierce Stacey and Barkatsas (2007). A 5-point Likert-scale survey is being used to examine student attitudes. It consists of 20 questions covering four each on mathematics confidence (MC), four each on technological confidence (TC), four each on attitude towards using technology to learn mathematics (MT), four each on affective engagement (AE), and four each on behavioral engagement (BE). The following subscale reliability levels are indicated by Cronbach's alpha values: MC, 0.87; MT, 0.89; TC, 0.79; BE, 0.72; and AE, 0.65. The second is a conceptual test to measure students' understanding of multiplication. The questions in the test were adapted from the developing essential understanding multiplication and division that published by NCTM (2012). It consists of 15 questions covering concept of multiplication (5 items), concentrate on multiplying multiples of ten (2 items), multiplication of a two-digit number by a one-digit number (3 items) and the multiplication of a three-digit number by a one-digit number (5 items).

3.3 Data Collection and Analysis

This study was a quasi-experimental design to investigate the effectiveness of Minecraft-based learning in enhancing students' conceptual understanding of multiplication and attitudes towards mathematics. The data collection for this study required 200 minutes. A non-equivalent control group design was utilized, with participants divided into two groups: a control group and an experimental group. Both groups initially completed a pre-test assessing their understanding of multiplication concepts, which required approximately 50 minutes to complete. Subsequently, the control group received traditional instruction on multiplication using a presentation-based approach, while the experimental group engaged in a series of Minecraft-based learning activities as shown in figure 1, which involved a 50-minute practice session on how to play Minecraft, followed by 50 minutes of gameplay and answering related questionnaires. After completing the intervention period, both groups participated in a post-test to measure their understanding of multiplication concepts and completed a questionnaire to assess their attitudes towards mathematics learning, both of which involved 50 minutes to complete. For data analysis, paired t-test and independent t-test were chosen for analyze within group and between group respectively. For students' attitude toward mathematics learning with Minecraft, one-way MANOVA was selected. All the data were analyzed using SPSS 22.0.

Figure 1. Presented the students interact with Minecraft individual.

4. Designing Task in Minecraft

Minecraft is a popular video game known for its open-ended gameplay, allowing players to use blocks to construct anything they can imagine. This freedom makes it an excellent educational tool, promoting creativity, problem-solving, and design skills. The ability to build complex structures with redstone mechanics introduces basic engineering principles, while its multiplayer mode fosters collaboration, teamwork, and effective communication, making it ideal for group projects. Many educators integrate Minecraft into various subjects. Research by Acar et al. (2024) found that using Minecraft improved students' academic performance and spatial perception. Therefore, Minecraft's flexible features make it a valuable tool for teachers, enabling them to create engaging and interactive learning experiences.

As shown in figure 2, the contexts of multiplication were designed in Minecraft, which consists of four stations to enhance multiplication understanding. In the first station, students plant five rows of sunflowers, with each row containing four sunflowers, illustrating multiplication as repeated addition. The second station involves organizing animal eggs, with four eggs of each type in five fenced areas, highlighting equal groups. The third station features a treasure hunt with boxes containing ten diamonds, introducing multiplication by ten and real-time data collection. Finally, the fourth station challenges students to choose between doors based on multiplication sentences, reinforcing their skills through interactive practice**.**

Figure 2. Flowchart of multiplication learning stations in Minecraft.

5. Result and Discussion

5.1 Conceptual Understanding of Multiplication

As shown in the table 1 , the results indicate significant improvements in conceptual understanding of multiplication within each group. The control groups' score increased from $\bar{x}$ = 20.64 (S.D. = 10.73, p<.001) to $\bar{x}$ = 26.14 (S.D. = 9.56, p<.001). Similarly, the experiment group's score also increased from $\bar{x}$ =14.35 (S.D. = 9.07, p<.001) to $\bar{x}$=22.95 (S.D. = 9.90, p<.001). According to the table 1 above, the results revealed that both the control and experimental groups demonstrated significant gains in their understanding of multiplication concepts. Interestingly, while students in the control group achieved higher post-test scores, reflecting their strong foundational skills and problem-solving abilities, the experimental group exhibited greater relative improvement. This suggested that both teaching approaches effectively enhanced students' mathematical understanding, with using Minecraft particularly boosting advancement in students who may have initially scored lower. These findings are consistent with the study by Bile (2022) found that utilizing Minecraft in educational settings boosts students' academic performance and strengthens their grasp of scientific concepts.

Table 1. *Conceptual Understanding Result on Multiplication within Group*.

Group	Test	N	$\bar{x}$	S.D.	t-score	p-value
Control Group	Pre-Test	22	20.64	10.73	-5.53*	<.001*
	Post-Test	22	26.14	9.56		
Experiment Group	Pre-Test	23	14.35	9.07	-6.12*	<.001*
	Post-Test	23	22.35	9.92		

*p<0.05

From the table 2, the study found that the control group initially outperformed the experimental group on the pre-test. Post-intervention, the experimental group, which used Minecraft as an educational tool, showed notable improvement, bridging the performance gap with the control group. Although both groups exhibited gains in the post-test, the differences in their scores were not statistically significant. This also aligned with the study of Bile (2022), which found that learning through Minecraft enhances students' learning outcomes and fosters their

understanding of basic scientific information along with the ability for interconnection and transversality.

Table 2. *Conceptual Understanding Result on Multiplication between Group*

Group	Control Group		Experiment Group		t-score	p-value
	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
Pre-test	20.64	10.73	14.35	9.07	2.13	.04*
Post-test	26.14	9.56	22.35	9.92	1.30	.20

*p<0.05

5.2 Students' Attitude toward Mathematics Learning with Minecraft.

In the table 3, it shown significant effects from Minecraft-based learning. Mathematics Confidence was a significant difference between control group and experimental group (F (5, 36) = 7.60, p = .009). Affective engagement (AE) with F (5, 36 = 14.53, p<.001). Learning mathematics through technology (MT) with (F (5, 36) = 13.84, p<.001). Technology confidence (TC) with (F (5, 36) = 21.79, p<.001). Behavioral engagement (BE) with (F (5, 36) = 31.29, p<.001). These results demonstrate Minecraft's effectiveness in enhancing confidence, engagement, and attitudes toward mathematics. According to the table 3, using Minecraft significantly enhances students' attitudes toward mathematics, especially in mathematics confidence (MC) and behavioral engagement (BE). The improvement in BE shows increased active involvement and motivation, promoting a deeper understanding of math concepts. This suggests Minecraft integration boosts enjoyment (AE) and engagement with challenging problems. This aligned with the study of Jensen and Hanghøj (2019), which found that while playing Minecraft by itself might not greatly improve mathematics education, using the game to foster meaningful mathematical practices can enhance student engagement and enjoyment. However, some students accustomed to traditional methods may initially struggle with technology confidence (TC), despite its high significance level.

Table 3. *The students' subscale means of attitude by time and multivariate MANOVA.*

Scale	Control Group		Experiment Group		F	η^2	p-value
	$\bar{x}$	S.D.	$\bar{x}$	S.D.			
MC	13.57	3.70	16.38	2.85	7.60	.160	.009*
AE	13.33	3.58	17.38	3.29	14.53	. 266	<.001*
MT	10.95	4.31	15.43	3.44	13.84	. 257	<.001*
TC	12.05	4.18	17.05	2.58	21.79	. 353	<.001*
BE	11.86	3.41	17.19	2.73	31.29	. 439	<.001*

*p<0.05

6. Conclusion and Limitation

The findings of this study suggest that Minecraft can be an effective tool for enhancing conceptual understanding of multiplication and fostering positive attitudes towards mathematics in primary school students. While the study acknowledges that some students may initially struggle with technology confidence due to their familiarity with normal learning methods. Therefore, this research underscores the potential of incorporating game-based learning in educational settings to motivate and engage students in mathematics. For limitation, using Minecraft in education presents some challenges. Firstly, correcting errors in Minecraft maps can be time-consuming, which can disrupt learning and require technical skills.

Additionally, the small sample size in this study may limit the generalizability of the findings, highlighting the need for future research with larger samples. Lastly, in a developing economy, limited resources make considerations around cost, technology access, and educator training crucial. Overcoming these limitations is vital to effectively using digital tools like Minecraft to enhance educational outcomes.

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