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Digital Game-Based Learning Interventions on Students' Numeracy Skills and Engagement

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Abstract

Numeracy skills play a crucial role in various aspects of life, both in mathematical learning and in daily life. Numeracy is the key to understanding and mastering various mathematical concepts. However, several research findings indicate that these skills are still relatively low. The low numeracy skills are attributed to the low engagement of students in mathematical learning. When students feel actively engaged in learning, they tend to be more motivated to learn and better able to understand the concepts taught. One effort to engage students in learning activities is by interestingly presenting learning content. Digital game-based learning is expected to improve numeracy skills and student engagement in mathematical learning. This study is a mixed-method research. The participants in this study were fourth-grade elementary school students divided into two groups: the experimental group and the control group. The instruments used were numeracy ability tests and observation sheets. The results of the study indicate that (1) the numeracy skills of students who received digital game-based learning are better than those of students who received traditional learning; (2) there are differences in the mean numeracy skills of students based on the intensity of playing games; and (3) Student engagement in digital game-based learning is classified as very high.

Keywords: Games-Based Learning, Numeracy Skill, Engagement, Mixed-Method, Elementary Student

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INTRODUCTION

Numeracy skills play a very important role in various aspects of life, both in mathematics learning and in everyday life (Goos et al., 2014; Thomas et al., 2024). Numeracy skills are the key to understanding and mastering various mathematical concepts (Purnomo et al., 2022). Every individual needs numeracy skills in daily activities, such as shopping (Beacom et al., 2022; Souza et al., 2022), managing personal finances (Bruine et al., 2021; Zhang et al., 2024), or making accurate and efficient decisions (Craig, 2018; Ratcliff & McKoon, 2020). Thus, numeracy skills are not only important in the context of mathematics learning at school but also crucial skills in everyday life.

However, the reality indicates that students' numeracy skills are categorised as low (Ndakularak et al., 2023; Rakhmawati & Mustadi, 2022; Adinda et al., 2022). Factors such as less engaging teaching approaches (Lavida et al., 2022; Skilling et al., 2021), math anxiety (Barroso et al., 2021; Süren & Kandemir, 2020), or lack of student involvement in the learning process can hinder achieving a deep understanding of mathematics. One of the main challenges in teaching mathematics is creating a learning environment that is motivating, challenging, and relevant to all students (Özhan & Kocadere, 2020).

This is where the concept of student engagement in mathematics learning becomes crucial. When students feel actively engaged in learning, they tend to be more motivated to learn and better able to understand the concepts taught. Conversely, students with better numeracy skills tend to be more engaged in mathematics learning (Balala et al., 2021), as they feel more confident in completing mathematical tasks (May, 2020) and more motivated to learn (Peters & Shoots-Reinhard, 2022), and more capable of understanding the taught mathematical concepts (Purnomo et al., 2022). Therefore, understanding the relationship between numeracy skills and student engagement in mathematics learning is important in efforts to enhance the effectiveness of mathematics education.

One intriguing approach to enhancing student engagement in mathematics learning is by leveraging technology (Sharma et al., 2024; Zhu et al., 2024), particularly in the form of digital game-based learning. Digital game-based learning offers a fun and challenging learning experience for students while providing opportunities to practice mathematical skills in relevant and meaningful contexts (Wulandari et al., 2024). With direct and responsive interactions, digital game-based learning can enhance student engagement in the learning process and provide instant feedback on their performance (Jivani et al., 2024).

As a learning tool, digital games offer a fun and engaging approach for elementary school students (Guan et al., 2024). In an interactive environment, students are not just observing or listening but also directly involved in the learning process (Alotaibi, 2024). They have the opportunity to actively participate, conduct experiments, and try solutions in a safe and supportive environment. The use of digital games has emerged as an engaging approach to enhancing students' numeracy skills (Bouchrika et al., 2021; Ningrum, 2023). In this approach, digital games serve not only as a means to deliver mathematical content but also as a tool to engage students actively in the learning process. This creates a stimulating and supportive learning environment that motivates students to engage more deeply in mathematics learning. Therefore, this research aims to investigate the effectiveness of using interactive games in improving numeracy skills and student engagement.

METHODS

This study is a mixed methods research, combining quantitative and qualitative approaches in data collection and analysis. It employs a quasi-experimental and observational design to compare the numeracy skills of students using digital game-based learning with those using traditional teaching methods. Additionally, observations will be conducted to analyse the percentage of student engagement in mathematics learning after using digital games.

The participants in this study consisted of fourth-grade elementary school students divided into two groups: the experimental group using digital game-based learning and the control group receiving traditional teaching. The experimental group consisted of two classes (N = 48), as did the control group (N = 49). The instruments used included numeracy ability tests and direct observation sheets completed during mathematics learning sessions with digital games. Researchers conducted observations during the learning sessions to record the frequency of student activities. The observed activities were operationally defined to ensure consistency in observation. The data collected included the number of students performing specific activities and their proportions relative to the total participants. This procedure was designed to enhance the validity and reliability of the observational data. Notes were also taken on student

engagement levels, peer interactions, and the comprehension of the material achieved during these sessions.

The quantitative data will be analysed using inferential statistical methods. The Mann-Whitney U test will be employed to compare test results between the experimental and control groups. Additionally, the Kruskal-Wallis test will be used to compare the numeracy skills of students who engage in digital games based on the intensity of their gameplay at home. Furthermore, qualitative data from observations will be analysed based on the percentage of student engagement. The percentage of student engagement will then be classified as shown in the following Table 1.

Table 1. Categories of Student Engagement

Percentage of Engagement	Engagement Categories
80,1% – 100%	Very High
60,1% – 80%	High
40,1% – 60%	Moderate
20,1 – 40%	Low
0,0% – 20 %	Very Low

By combining quantitative and qualitative approaches, this research is expected to provide a comprehensive understanding of the effectiveness and role of digital games in enhancing students' numeracy skills, as well as the factors influencing their implementation in the elementary school learning environment.

RESULTS & DISCUSSION

Results

The data obtained in this study consist of post-test scores of numeracy skills in the experimental and control groups as well as the results of observations on student engagement during learning using digital games. Table 2 presents the data on students' numeracy skills based on the research findings.

Table 2. Descriptive Statistics of Numeracy Skills

Statistic	Digital Games	Traditional
N	48	49
Mean	88,75	82,85
Std. Deviation	8,64	6,29
Maximum	100	100
Minimum	78	78

From Table 2., we obtain information that the average numeracy skills of students who received digital game-based learning are higher than the average numeracy skills of students who received traditional teaching. However, these results may not necessarily be significant. Therefore, it is necessary to conduct a test of mean differences using inferential statistics. Prior to this, an assumption test needs to be conducted to determine whether the obtained data is normally distributed. The results of the data normality test using the Shapiro-Wilk test can be seen in Table 3.

Table 3. Normality Test Results for Numeracy Skill Data

Kelas	Statistic	df	Sig.
Digital Games	.845	48	.000
Traditional	.777	49	.000

In Table 3, it is known that the p-value for both classes < 0.05; thus, it can be concluded that the data is not normally distributed. Since the data is not normally distributed, the test for data homogeneity is not required. Therefore, to test the difference in mean numeracy skills between groups, the non-parametric Mann-Whitney U test is used. The results of this test can be seen in Table 4.

Table 4. Mann-Whitney U Test Results

Mann-Whitney U	726.500
Wilcoxon W	1951.500
Z	-3.336
Asymp. Sig. (2-tailed)	.001

The results of the test for mean differences above show that the p-value (2-tailed) < 0.05. This means that there is a significant difference in the mean numeracy skills between the group that received digital games and the traditional class. Referring to the descriptive statistics in Table 2, where the average numeracy skills of students who received digital game-based learning are higher than those of the traditional class, it indicates that the numeracy skills of students who received learning with the assistance of digital games are better compared to those who received traditional teaching.

Before providing treatment to both classes, observations were conducted in the class that received digital game-based learning to determine their intensity in playing games at home. The intensity of game playing was divided into three categories, as depicted in the following descriptive statistics:

Table 5. Descriptive Statistics of Numeracy Skill Based on Intensity of Playing Games and Normality Test Results

Class	Intensity of Playing Games	Mean	Std. Deviation	Normality Test (sig.)
Digital Games	Often	91,27	8,07	0,001
	Seldom	84,00	8,54	0,000
	Never	89,64	4,72	0,407

The results in Table 5 indicate differences in the average numeracy skills based on their intensity. However, these differences cannot yet be considered significant. Therefore, a test of mean differences for the three groups of data was conducted. Similar to before, a normality test was first conducted for each group of data to determine the type of test to be conducted. From Table 5, we can see that there are p-values for two groups of data that are < 0.05. Thus, the conclusion is to conduct a non-parametric statistical test as the data does not meet the assumption of normal distribution. The test conducted is the Kruskal-Wallis test. The results of this test can be seen in the following Table 6.

Table 6. Kruskal Wallis Test Results

Chi-Square	8.511
df	2
Asymp. Sig.	.014

The results of the Kruskal-Wallis test above show that the p-value is < 0.05. Therefore, it can be concluded that there are differences in the mean numeracy skills based on the intensity of game playing.

In addition to depicting numeracy skills, this research also observed student engagement during digital game-based learning. The results of this observation are summarised in Table 7. Based on the data in Table 7, the average student engagement obtained is 87%, indicating that student engagement in digital game-based learning falls into the category of very high.

Discussion

The numeracy skills of students who receive digital game-based learning are better than those who receive traditional teaching. These research findings highlight the effectiveness of innovative learning approaches in improving mathematical understanding and high-level skills (Kwangmuang et al., 2021; Olis et al., 2023). This discovery is consistent with the growing trend where technology, especially digital games, is increasingly recognised as a tool with the potential to enhance learning outcomes (Karakoç et al. & Yıldırım, 2022; Shi et al., 2022). Digital games offer an engaging and enjoyable learning environment where students not only acquire knowledge of mathematical concepts but also actively engage in the learning process (Akman & Çakır, 2023; James et al., 2024; Xiao & Hew, 2024). Direct interaction with learning materials through games can help students better understand mathematical concepts as they have the opportunity to try, fail, and learn from their own experiences (Ilbeigi et al., 2024; Kulakaç & Çilingir, 2024). This approach provides evidence that technology is not just an additional tool but also an integral component in effective mathematics learning in the digital era.

Furthermore, the results of this research indicate that digital game-based learning can reach students with diverse learning styles. Traditional approaches to mathematics learning may not optimally accommodate the individual learning preferences of students. However, with digital games, students have the opportunity to learn through visualisation, direct interaction, and experimentation, which may better align with their learning styles (Hassan et al., 2021). Nevertheless, although the research findings demonstrate the superiority of digital game-based learning, it is important to remember that digital games are not a one-size-fits-all solution to all challenges in mathematics learning. It is important to ensure that the use of digital games does not replace the essential human interaction between teachers and students. Teachers still play a crucial role in providing guidance and feedback and guiding students through the learning process.
(Marklund & Alklind, 2012; Yunimuninggar & Fardhani, 2024). Thus, the results of this research underscore the importance of integrated and holistic approaches in enhancing students' mathematics learning.

The research findings reveal differences in mean numeracy skills based on the intensity of game-playing, which indicates that students with high interactive game-playing intensity tend to achieve higher average numeracy skills. These results contradict the findings of Aklima's (2019) research, which stated that the higher the intensity of students playing games, the lower their achievement. However, considering that the games used in this research are 3D games, students tend to have more time and

opportunities to become familiar with the interface and navigation in these 3D digital games. They can also more effectively develop skills needed to interact with the virtual environment, such as navigation, problem-solving, and spatial skills (Chicchi et al., 2021).

The research findings indicate that student engagement in interactive game-based learning falls into the high category and signifies the success of this learning approach. The high level of engagement reflects the active participation of students in the learning process, where they are actively involved in exploration, interaction, and problem-solving (Zhao et al., 2021). The use of digital games enables students to learn more enjoyably and engagingly, which naturally promotes higher engagement than traditional learning methods (Ilbeigi et al., 2024; Lopez-Fernandez et al., 2021).

High student engagement in digital game-based learning also indicates that this approach is capable of sparking students' intrinsic interest in mathematics (Shi et al., 2022). This can change students' perceptions of mathematics from something boring or difficult to something interesting and valuable (Almusharraf, 2023; Xie et al., 2021). By feeling engaged in learning, students are more likely to be motivated to learn and achieve better outcomes (Yu et al., 2021).

Moreover, the high level of student engagement in digital game-based learning provides evidence that technology can be an effective tool for enhancing student participation in learning activities (Carstens et al., 2021; Tsay et al., 2020). The use of technology, such as digital games, can create inclusive learning experiences where every student feels supported and accommodated in the learning process. By considering students' preferences and needs, teachers can design learning experiences that can captivate the interest and engagement of students from various backgrounds and ability levels. As a result, digital game-based learning approaches can be an effective means to create a learning environment that is motivating, challenging, and student-centred (Coleman & Money, 2020; Hassan et al., 2021).

CONCLUSION

The use of digital games in mathematics education has been proven to be more effective in developing students' numeracy skills, especially when students are engaged with high levels of gameplay intensity. The very high level of student engagement in learning with digital games reflects the potential of technology to create an inclusive learning environment, motivating students from diverse backgrounds to engage in the learning process actively. Further prospects arising from this research include exploring the most effective types of digital games, factors influencing gameplay intensity, and practical applications in the development of technology-based curricula and teacher training. Thus, this research provides a strong foundation for the development of innovative, technology-oriented mathematics education approaches to support students' mathematical understanding.

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Table 7. Observation Results of Student Activities During Digital Game-Based Learning

No	Student Activity	Frequency Observed (N=48)	Proportion (%)	Operational Definition
1	Students bring cellphones/tablets to learn with interactive games	48	100	Students bring their devices to class for use during game-based learning sessions.
2	Students show enthusiasm for digital games-based learning	40	83	Enthusiasm is measured based on facial expressions, full attention to the screen, and positive comments.
3	Students learn math concepts in less than 10 minutes	36	75	Time spent by students to understand a mission or challenge within the game.
4	The students repeat missions in the digital games whose scores are not perfect.	48	100	Students retry game missions until achieving a maximum score.
5	The students ask the teacher when completing missions in the games.	39	81	Verbal interaction between students and the teacher related to questions about game missions or challenges.
6	The students collaborate with other students to complete missions in the games.	46	95	Two or more students work together on a device or discuss strategies to complete missions.
7	The students achieve a score of 80 or higher on the numeracy skill test within the games.	38	80	Scores were obtained from the numeracy tests embedded in the digital game.
8	The students play Mobile Math (digital games) at home without being asked by the teacher.	42	87	Students report playing the game independently at home without additional instructions from the teacher.

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