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Enhancing Early Childhood Mathematics Skills Learning through Digital Game-Based Learning

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Abstract. The present study investigates the unique impact of digital game-based learning (DGBL) on children's mathematical problem-solving skills, with a particular focus on both immediate and long-term effects. While much of the existing research on DGBL explores its general benefits, this study differentiates itself by examining how DGBL specifically enhances cognitive skills. The study included 120 students, 61 of whom were assigned to an experimental group taught using digital games, and 59 to a control group taught through traditional methods. The research design incorporated the development of a customized game-based learning material and a comprehensive mathematical problem-solving assessment. The results revealed that the experimental group significantly outperformed the control group in both immediate and delayed post-tests, which underscores the effectiveness of DGBL in enhancing students' retention of mathematics well beyond the initial learning phase. This suggests that DGBL is not only effective in helping students grasp mathematical concepts in the short term but also in

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strengthening their ability to retain and apply these concepts over time. Moreover, the study goes further by highlighting the long-term cognitive benefits of DGBL, such as the development of critical thinking, quick decision-making, and problem-solving skills. This aspect of the study distinguishes it from other research in the field as it emphasizes not just short-term academic performance, but also lasting improvements in key cognitive abilities. Based on these findings, it is recommended that teachers integrate digital game-based learning into their teaching strategies. This integration can enhance student engagement, motivate learners, and facilitate understanding of mathematical concepts.

Keywords: digital games; educational games; student performance; Jordan; mathematical problem-solving; cognitive skills; retention; educational technology; student engagement

1. Introduction

Mathematics helps stimulate logical reasoning, problem solving, and cognitive skills, especially at the early childhood education. These competencies are not limited to the classroom setting, but rather, they are helpful in overcoming numerous challenges in life (Hassan et al., 2012; Lasut & Bawengan 2020). Using mathematics, children (5-8 years) can design a formula and a set of methodologies to tackle identified problems and arrive at fairly complex but systematic solutions. Therefore, children must learn how to approach and resolve issues from a logical perspective and how to think critically in academic and real-world contexts (AlAli & Al-Barakat, 2024a; Sarama & Clements, 2015). Problem solving skills should be cultivated from an early age as these crucial skills can intersect with personal, work and social life, helping children navigate their way (Khasawneh et al., 2022).

Solving a mathematical problem is not solely about using known formulas and computations. It encompasses one's ability to analyze the given problem, divide it into smaller logical parts, and finally, solve it step by step. Children equipped with problem-solving strategies can approach problems in different ways and utilize the most effective approach that aligns with the task at hand (Aladé et al., 2016; Berkowitz et al., 2015). These skills are not confined within the bounds of mathematics but also help the student in developing higher-order thinking skills that can be implemented in real world environments. They also enhance a person's ability to address a plethora of issues that arise in their daily lives. Nowadays, technology serves as one of the most powerful tools available for developing problem-solving abilities, especially in mathematics education. It is no longer an additional device of assistance, but has become integrated as a fundamental aspect of the education process with more developed learning techniques and instant feedback that improve comprehension (Bray & Tangney, 2016; Calder, 2015). These devices make it easy for children to approach mathematics problems in more creative ways, thereby adding flexibility to learning (AlAli & Al-Barakat, 2024b; Kermani, 2017). By integrating technology into the learning experience, children can actively interact with the material and receive prompt assistance when encountering difficult mathematical concepts.

One of the notable innovations in education is digital game-based learning (DGBL), which has proven to be an effective approach in learning and training. Alkhede and Holmqvist (2021) affirm that DGBL incorporates the notion of playing digital games into teaching in order for it to be more captivating. This is in a bid to create a unique space for student-driven learning where there is integration of problem-solving and critical thinking. DGBL is especially remarkable because it awakens the motivation of learners to participate fully in the learning process, hence making the learning of mathematics pleasurable and productive. Children are taught how to use digital games in the classroom and are then given game problems to solve. This not only enhances learning but also enables the students to develop higher order thinking skills such as analytical reasoning, logic, and even creativity (Al Khateeb, 2019; Hussein et al., 2022).

The impact of DGBL on education has been studied in several reviews, one of which is that of Pan et al. (2022), who reviewed 43 studies focusing on the use of digital games in mathematics education. They found that students' behaviors, working memory, and knowledge acquisition were greater among students who participated in game-centered mathematics classes than among those who participated in mathematics extracurricular programs. Games, strategies of various types and also puzzles were highly successful in increasing students' abilities in computation. Higher-level cognitive skills were developed through role-playing and simulation games. These games make it possible to implement a new approach to instruction which emphasizes motivation and drills to practice and reinforce students' knowledge base more deeply (AlAli & Al-Barakat, 2024c).

Furthermore, Hussein et al. (2022) also noted that DGBL proved useful in assisting learners solve many topics in mathematics such as operations in numbers. It is also evident from their review that DGBL did not only enhance the mathematics knowledge of the learners but further enhanced their cognitive skills and motivation. Hence, DGBL is accepted to be one of the new, innovative approaches in the teaching learning process, particularly in primary schooling where the major objective is to teach the learners basic mathematics, the concepts of reasoning, and active learning.

The engaging characteristic of DGBL promotes self-discipline in students through tackling challenges that require perseverance in order to succeed; rather than being disheartened by complexities, students learn to tackle mathematical concepts with inquisitiveness and determination, guided by their experience of overcoming obstacles in the game setting (Al-Barakat et al., 2023; Barros et al., 2022; Baul & Mahmud, 2021; Deng et al., 2020; Hawamdeh et al., 2025). This process helps to foster self-belief as students begin to notice the changes in their ability to solve problems, which in turn motivates them to take on bigger challenges. Other than advancing one's ability to solve mathematical problems, DGBL also cultivates important life skills and facilitates the emergence of a growth mindset where challenges are information in disguise (Lasut & Bawengan, 2020).

In addition, the prompt feedback offered through games is also helpful in capturing the interest of students. Studies, including those done by Hui and Mahmud (2023), have shown that DGBL leads to greater student engagement and therefore helps to turn classrooms into animated places where students are continuously interested and willing to learn. This type of game-based learning enables teachers to change their instructional methods instantly for specific students which improves their achievements (Al-Barakat & Al-Hassan, 2009; Balaskas et al., 2023). This approach not only expands the learners' grasp of the various concepts of mathematics, but also develops other useful skills such as imagination, critical reasoning, and solving problems.

There are DGBL challenges that Jordanian students face: limited resources, outdated teaching methods, and primitive assistive technology in rural areas, all of which are interconnected. As a result, students in Jordan often struggle to develop problem-solving skills, particularly in subjects such as mathematics. Classroom technology can be regarded as a solution; however, its effect on students' problem-solving abilities, especially in mathematics, tends to be negative. It is clear that DGBL has the potential to address these issues as it is able to foster motivation and make challenges fun, all without the need for sophisticated technology.

Frequently, children are not taught using active and constructive learning so that they can develop critical and analytical reasoning. The integration of DGBL is considered to be filling a gap in teaching needs that provides innovative enactments, which are not currently offered. With the adoption of video games into lessons, children become proactively engaged in tackling a variety of theoretical and practical methods of mathematics professionally, and teachers will be able to motivate learners to engage actively with the material rather than passively memorize it. With these changes, children will be able to excel in comprehension.

2. Problem Statement

The issue that needs to be addressed is the issue of unsatisfactory results gathered from the Jordanian children's performance in Trends in International Mathematics and Science Study (TIMSS), especially in the areas of mathematics and science. The results from this examination highlighted that children's performance in mathematics has significantly failed at both regional and global levels. In the results of TIMSS 2015, Jordan scored 388 in mathematics for 4th-grade children compared to the average score of 539 in the participating countries. This mark exposes a sizable deficit of primary level understanding of mathematics, specifically in concepts of addition and subtraction, interactions and calculations. The essence of this study is the poor performance of Jordanian children as evidenced by the analysis of the results from the TIMSS. Moreover, the teachers and children with whom the researchers interacted noted that numerous learners face challenges with the use of simple mathematics, which raises concerns regarding the overall mathematics education in the region.

Choosing effective solutions that foster the growth of children's problem-solving abilities is a complex but important task as it helps them in the long run. As children nowadays have high levels of engagement with technological devices such as smartphones and computers, it is worth thinking about utilizing digital game-based learning as one of the solutions. Game-based learning offers an advantage over more traditional forms of instruction in subjects such as mathematics, especially geometry and measurement, as children can develop and practice understanding and problem-solving skills in a more fun and interactive context.

The study endeavors to answer the following questions:

1. Are there statistically significant differences at the ($p \leq 0.05$) level among the early childhood education learners with regard to problem solving skills in mathematics as a consequence of learning using electronic game-based versus traditional approaches?
2. Two months after the experiment, are there statistically significant differences at the ($p \leq 0.05$) level in the performance of the experimental group, who learned through an electronic game-based learning unit, in the immediate (real-time) and delayed mathematical problem-solving skills tests (retention)?

3. Significance of the Study

This study has considerable relevance according to the following factors that indicate the need to improve the quality of education concerning enhancing children's ability to solve mathematical problems. First, this research aligns with the recommendations of the National Council of Teachers of Mathematics (NCTM) which indicated that measurement and basic geometry should be taught at all grade levels. The aim has also been to foster problem-solving skills in mathematics which complements the goal of this research, namely to improve these skills among children. It has been noted that children can be taught using digital games where they are able to interact with and appreciate the concepts of mathematics in a more effective manner. This develops critical and analytical thinking skills in children, which forms the core principle of NCTM regarding teaching mathematics.

Second, this study is different from others as it analyzes the potential of digital games in the teaching of mathematics, therefore implying a departure from the conventional methods of educational research. Digital games are an excellent means of aiding students' attention and imagination: they depict a context that is both interesting and educational and in which they actively learn through making mistakes and playing with the material. They make the children work harder and be more willing to learn; moreover, they also require them to consider different perspectives of certain mathematical concepts, which improves their understanding.

In addition, digital games afford an educational domain that facilitates unprecedented interaction with the lesson content, thus fostering the sustainability of learning instead of relying heavily on lectures or written tasks, which may be dull or uninteresting to some children. Digital games also enable children to practice lessons through repetitive tasks and exercises, strengthening their skills in the process. In turn, they develop more sophisticated skills in solving mathematical problems effectively.

Ultimately, children get to improve their strategic and analytical thinking through these games while facing multiple mathematical problems. Digital games not only teach math concepts, but also foster critical thinking, which is vital for solving issues. This could have a favorable impact on children's achievements in mathematics and other subjects. Children can be inspired to innovate and acquire strategies that are helpful for solving mathematical problems in an active and enjoyable way. Consequently, the current study makes a significant contribution to the mathematics education literature with respect to the improved quality of education with the use of newer technology which assists children in acquiring mathematical problem solving skills as well as motivating them towards learning.

4. Methodology and Procedures

4.1 Study Design

In a bid to solve the research problem, the study was conducted using a quasi-experimental approach with two groups; an experimental and a control group. The experimental group focused on learning mathematical skills such as addition and subtraction within a single session, using a digital game-based learning unit. The control group, on the other hand, practiced those skills through conventional methods. This element of the study has been included to examine whether young children are able to solve mathematical problems more effectively using games as opposed to traditional teaching methods.

In order to ensure that the groups were identical, selected participants were randomly allocated to either the control or experimental group based on their prior knowledge and academic performance. As an indicator of their mathematic problem-solving skills, both groups took pre-tests prior to the instruction phase. Specifically, the pre-tests sought to determine their understanding of addition and subtraction. The means and standard deviations of the children's pre-test scores were computed to confirm that both groups had similar starting levels in their problem-solving abilities.

The project commenced with a pre-test and then an instructional phase. The experimental group played games on adding and subtracting through problem-solving tasks, while the control group studied using worksheets, drills, and lectures. After the phases of instruction had been completed, each group was given some problems to test how much improvement they had made in their problem-solving skills. The purpose of the tests was to determine how well the students could perform actions of addition and subtraction.

Conducting both pre- and post-test evaluations enabled the researchers to analyze the two groups and their performance with the use of digital games and sophisticated mathematics problem-solving skills. This method facilitated the estimation of effectiveness of learning via digital games in comparison to more conventional approaches.

4.2 Study Participants

This research focuses on 2nd-grade students studying in Amman private schools in Jordan. Eight schools were purposefully selected; four of them were for the experimental group and the other four were for the control group, depending on the willingness of the school principals, teachers, and their cooperation. A total of 120 children were chosen as subjects for the study. They were divided into two groups: there were 61 children in the experimental group who were instructed on problem solving with the aid of digital games, and 59 children in the control group who received the same training as the experimental group, but with the traditional methods incorporating face-to-face explanations and classroom debates without the use of digital technology. The research was conducted during the second semester of the 2023/20204 academic year. This allowed the researchers to focus on the impact of digital gaming on developing mathematical skills during the time when children were already familiar with some of the mathematics topics.

4.3 An Electronic Games-Based Learning Unit

The focus is the simultaneous development of young children's problem-solving capabilities in mathematics along with critical thinking skills using an interactive engaging platform. The unit was designed in a sequential manner that begins with the preparation phase where the educational objectives are clearly specified in order to master important mathematical skills such as division, addition, and subtraction. These skills are intended to be modifiable to accommodate young learners of varying degrees of understanding comprehension. Shopping, meal serving, and other similar activities are used to explain the concepts to achieve greater imaginative thinking. The goal is to achieve a deep understanding of arithmetic that can be applied in different real-life situations in the future.

The aim of the game from the beginning was to provide an appealing and motivational educational experience for children with the proper balance between entertainment and education. The ADDIE model, which divides the process into stages of analysis, design, development, implementation, and evaluation, adds a level of organization and structure to the learning process. In the analysis phase, it was essential to understand the children's needs and their knowledge levels in order to create appropriate educational objectives, whereas, in the design stage, the various elements of the game that involve the progressively more challenging storyline along with motivational rewards were defined. This enabled children to play a game that is crafted with elements of mathematics while doing so, while interacting with the character throughout the adventure.

To ensure that the games would capture the users' attention visually while being educational, the designers chose specific technical instruments targeted at younger children such as Unity for 3D environments and Scratch for simpler games. These specific tools were selected as they support different ways of engagement in digital games for young children. For example, 3D adventures games focus on the problem-solving skills of older children as they explore the game's environment. On the other hand, younger children are better served with simpler visual element interactive puzzle games that introduce basic number and arithmetic concepts. Mental engagement is stimulated through the inclusion of animations, sounds, and colors. Young children can be engaged and encouraged to think through carefully designed interactive interfaces that support the learning of important mathematical symbols such as numbers and even geometric shapes.

Upon the creation of the game prototype, the production stage entails sufficient testing to confirm that all the technical features operate correctly. This encompasses checking the child's interaction with the characters, mathematical elements, and other navigational tasks programmed in the game. Therefore, the graphics, educational content, and sophistication of the presented challenges are modified based on suggestions from professionals in mathematics education, child development, and information technology. For instance, such changes are carried out so that the game is intrinsically enjoyable, which is essential in aiding young children who experience challenges in overcoming hurdles.

The school then adopts the game as an integral part of daily classroom activities. The game is played by teachers so that young children understand the basic mathematical concepts of addition and subtraction as they progress through various challenging levels. This game enables the children to resolve issues that they face in their daily life that require the application of mathematics, thus improving their overall problem-solving abilities. This prevents the learning process from being dull as little children learn to solve important problems in an active way. It also allows teachers to keep track of the children's achievements and offer assistance as needed.

A crucial part of the implementation phase is to track the progress made by all children over time. This includes having teachers observe young children, having children take mathematical pre- and post-tests, and having the children receive instantaneous feedback from the game. The game monitors each child's performance and provides detailed reports on the tasks completed and the time spent solving problems. This data is beneficial in pinpointing issues that require corrective measures, and in providing further assistance to ensure that learners succeed.

To ensure the game is correctly incorporated in the classroom, teachers must undergo a two-week training workshop. During the first week, the teachers are introduced to the principles underlying educational video games, particularly relating to their use for mathematical problem solving. Some of the training activities include demonstrations on the effective use of the game in the participants' classrooms. During the second week of training, teachers are assisted by trainers to practice using the game in real classrooms. This kind of training equips the teachers with skills to monitor student involvement, motivate them and modify lessons based on the students' performance.

Therefore, the electronic games-based learning unit offers a unique and innovative way of teaching mathematics. It is captivating and interesting, yet it helps young children learn to solve problems by using mathematics as part of their day-to-day activities. Through evaluation, accommodation, and teacher education, this policy enables every child to learn at their own pace while gaining confidence and a positive attitude towards mathematics. In view of this, the unit aims to integrate technology into the learning process to prepare the pupils for future academic challenges and make them more willing and able learners.

4.4 Mathematical Problem-Solving Test

The purpose of this test is to assess the mathematical problem-solving skills of young children in addition and subtraction. The first version of the test was constructed with 15 problems that were designed to evaluate not only problem-solving skills, but also the retention of mathematical concepts over time. The test was developed based on the researchers' practical experience in teaching mathematics to early childhood pupils, with questions needing logical steps and relevant actions from children. Each problem has sections that are critical to problem solving, such as understanding the issues, obtaining relevant information, selecting relevant operations, and executing the operations to attain a solution.

This test equally measured both short-term retention (understanding and utilizing the concepts on-the-spot) and long-term retention (the ability to retrieve and utilize the concepts after a delay). In particular, young children's capacity to recall concepts they learned from the game-based learning environment was measured through follow-up assessments conducted after a period of time to measure their performance on addition and subtraction tasks for novel problems.

The problem questions are based on the general issues that most young children face in their day-to day-living. For example, children were asked how many fruits would be left after a friend takes some, or how many fruits there would be if apples and bananas were bought. Such types of questions were meant to enable young children to think critically and have a certain level of mathematical understanding and reasoning. It required them to comprehend the assignment, recognize the provided information, determine the needed processes, and execute those steps appropriately to obtain the solution. The incorporation of both immediate and delayed post-tests differentiates this research from others by evaluating how the game-based digital learning not only enhances the ability of young children to solve problems but also helps them remember, retain, and understand mathematical concepts.

4.5 Reliability and Validity of the Test

To ensure the face validity of the test, the test was sent to 13 experts in mathematics education, early childhood education, measurement and evaluation. Based on their replies, some of the items were rephrased and three problems were omitted. Therefore, the actual test comprised ten items. In an attempt to determine whether the test was reliable, a pilot test was performed on a sample of 21 participants. The participants were asked to complete the test in order to assess its clarity, the time necessary for test administration, and its reliability. The average time required to complete the test was calculated to be 45 minutes. The difficulty indices of the test were computed to 0.79 and the discrimination indices to 0.77.

In seeking to measure construct validity, the analysis conducted in the study employed McDonald's omega and composite reliability (CR), and checked discriminant as well as convergent validity. According to the results of the study, McDonald's omega and CR were 0.88 and 0.89, respectively which are all above the 0.70 mark. This explains why the study had high internal consistency. Furthermore, the average variance extracted (AVE) was calculated to be 0.68, and it was found that the value meets the recommended benchmark of 0.50. The discriminant validity coefficients would be set as square root of the AVE or convergent validity and their coefficients would be set as greater than the inter-correlations between the latent variables or factors. It was determined that the result was greater than the set minimum value. This shows that these results meet the requirement set for the scale and are therefore reliable and valid (AlAli & Al-Barakat, 2022).

Confirmatory factor analysis (CFA) was carried out with Amos statistical software to analyze the factor validity of the measurement tool. To assist in diagnosing structural equation modeling (SEM), CFA is one of the core components which help in relationship mapping of the latent variables as well as helping in dataspace patterning. This method is useful in various stages of instrument design such as design of the new instrument, validation of the constructs, and evaluating the impact of the method on the outcome. By confirming the initial dimensions and factor loadings within the instrument, CFA provides evidence for the latent structure underpinning the instrument. Therefore, this moves comprehensively and improves the psychometric fidelity of the measurement instrument (AlAli & Al-Barakat, 2022). To achieve factorial construct validity, the version of the test was administered to the sample for this study. CFA was adopted for item alignment of the scale items with the whole scale looking at the loading values of each item whole scale as demonstrated in Figure 1. Loading factors with values below 0.40 were deemed as an unacceptable set of criteria (AlAli & Al-Barakat, 2022). The analysis was proved to be valid because all items were met, and the set of items was confirmed to have achieved the criteria of greater than 0.40 for loading factors. A CFA is displayed in the results of Figure 1:

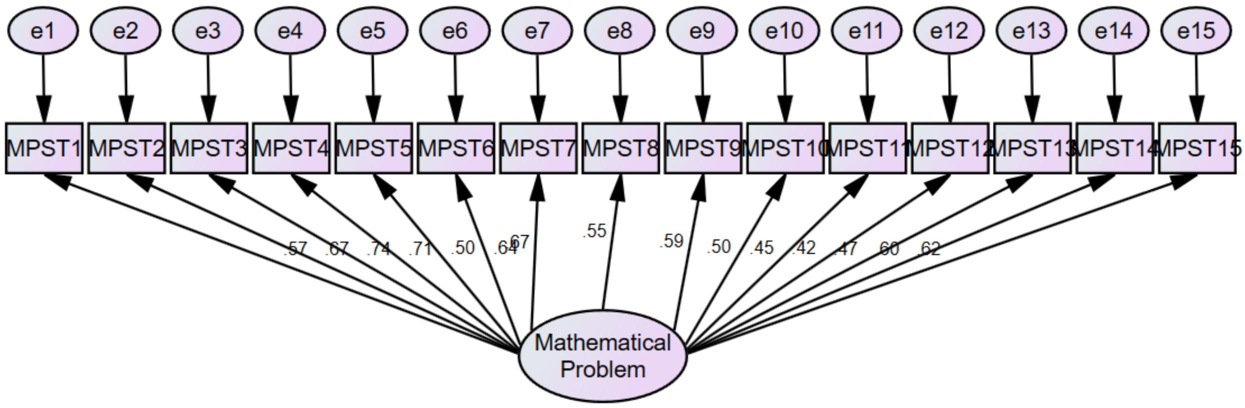

Figure 1: The results of a confirmatory factor analysis, illustrating the relationships between individual test items and the overall test construct, along with their respective factor loadings

4.6 Data Collection and Analysis

After compiling the educational material that was based on electronic games, the researchers designed the test and obtained consent from school principals and teachers. Before conducting the teaching process, some measures were taken to ensure that both experimental and control groups were academically equal. A pre-test measuring problem-solving skills in mathematics was administered to pupils in both groups. They were recorded using mean score and standard deviations of the pupils' t-scores. A t-test was conducted to determine the differences between the two groups. The results of the pre-tests are illustrated in Table 1:

Table 1: Pre-test Results for the Mathematical Problem Solving Test

Group	No.	Mean	St. dev.	T-value	Sig.
Experimental	61	8.75	1.98	0.574	0.773
Control	59	8.80	1.79		

Table 1 shows that there were no statistically significant differences between the performances of the two groups on the pre-test, indicating that participants from both groups had similar skills before the teaching process commenced. This confirmation of validity helps in explaining the results of the study because the subsequent differences in performance on the post-test could be due to differences in student instruction using video games rather than differences between the two groups.

The teachers selected for the experimental group were trained on how to incorporate electronic games into lessons effectively. In this case, the pupils were biased because the researchers had controlled the assignment of pupils to conditions. The control group received the same units but was taught using conventional methods.

Both the experimental and control groups were given the post-test of mathematical problem-solving. The data were analyzed; mean scores and standard deviations were computed for this test. One-way ANCOVA was performed to analyze the data and to test the hypothesis of the study to determine the effect of electronic games in teaching problem-solving skills compared to the traditional approach.

5. Results of the Study

5.1 Problem-Solving Test Results

The objective of this question is to determine the effectiveness of an educational unit based on electronic games in improving mathematical problem-solving skills in young children. The means and standard deviations for the pre-test and post-test of mathematical thinking skills were calculated according to the teaching strategies "digital games-based learning" and "traditional" to achieve this, as illustrated in Table 2:

Table 2: Post-Test Results for the Mathematical Problem-Solving Test

Group	No.	Mean (Pre-test)	St.dev. (Pre-test)	Mean (Post-test)	St.dev. (Post-test)
Experimental	61	15.53	6.50	37.49	1.04
Control	59	15.80	5.34	23.83	3.37

*mean score = 40

As revealed by the data in Table 2, there is a difference between the group that used digital games as a method of teaching and the group that did not. The experimental group in the pre-test had a mean of 15.53 with a standard deviation of 6.50, indicating that the pupils' level of academic achievement in their assessment of mathematics was moderate and quite achievable. After digital games were used in teaching, the mean score for the post-test was 37.49 with a standard deviation of 1.04. This demonstrates that young children's abilities to solve mathematical problems have increased because there is less variation among the pupils' scores. This result underscores the effectiveness of digital games in improving children's overall mathematical thinking.

Regarding the control group which relied on conventional methods of learning, the pre-test results indicated a mean score of 15.80 with a standard deviation of 5.34. This demonstrates that, as anticipated, the level of problem-solving skills of the pupils in the control group was lower than that of the experimental group and there was less range in student achievement. In the post-test, the mean score, as expected, increased to 23.83 with standard deviation of 3.37. This demonstrates improvement in student achievement, though it did not reach the level of the experimental group. This show that traditional education managed to enhance the learners' mathematical skills but not as considerably as was observed with children who were taught mathematics using digital games.

A one-way ANCOVA was conducted to test for effects of teaching strategy (digital game-based learning or traditional) on problem-solving skill measurement in the post-test to determine whether these apparent differences are statistically significant. The analysis results of the one-way ANCOVA are shown in Table 3:

Table 3: Results of One-Way ANCOVA for the Post-Test of Mathematical Problem Solving

Source of Variation	Sum of Squares	df.	Mean Square	F-value	Sig.	Eta-Squared (η²)
Pre-Performance	132.546	1	132.546	16.784	0.001	0.120
Teaching Strategy	316.546	1	316.546	19.752.	0.000	0.359
Error	705.599	117	18.206			
Total	1101.001	120				

As indicated in Table 3, the results of the one-way ANCOVA on the student pre-test and the post-test strategy score showed that there is a statistically significant 3-way interaction ($p<.05$). This means that both pre-test scores and the strategy used in teaching pupils significantly affected the increment of pupils' mathematical problem-solving skills. However, the student learning strategy was the most dominant and was the measure of greatest importance.

The initial scores of the participants positively influenced their post-test scores as is evident from the 16.784 F-value registered alongside the 0.01 p-value witnessed. These readings are lower than the essential 0.05 standard significance level. This permits the conclusion that the pupils' prior knowledge and skills that were measured in the pre-test were a significant factor in the post-test performance. The estimate value of Eta-squared is 0.120 (moderate effect) so it seems reasonable to state that 12% of the difference in the final score is attributable to the initial score. Even though there is a significant relationship that is reported between the pre-test and post-test performance, the impact is not as great as that of the teaching strategy.

The different teaching strategies used in class seem to have affected the students' post-test scores. The F value for the teaching strategy is markedly higher at 19.752 and the p-value of 0.000 shows that the effect was statistically significant. This tends to confirm that the different strategies of teaching the students, such as using digital game-based learning compared to more conventional ways of teaching, probably made a significant difference towards improving the students' mathematical problem-solving abilities. The Eta-squared value of 0.359 suggests that it accounts for 36% of the teaching strategy applied to the post-test scores, suggesting that it was the cause. This indicates that there is a fairly large difference between the two teaching methods in student learning outcomes, with digital game-based learning appearing to have had a significantly positive impact.

However, the error term (705.599) represents the variance in scores as a result of factors other than pre-test and the students' taught method that was not accounted for. Although this component of the analysis is useful in assessing the fit of the model, its magnitude here suggests that the teaching strategy and the initial test scores largely explain the post-test scores, leaving only a small amount of variance that is not explainable.

These findings together have pointed out the importance of teaching methods, particularly, the digital game-based approach in developing students' ability to solve mathematical problems. The pre-test scores set the minimum standard, and while they are important, it is the teaching methods used that have the biggest impact on the performance. These findings corroborate the assumption that students' engagement and cognitive skills development, especially in mathematics, can greatly benefit from the use of interactive digital games.

5.2 Delayed Problem-Solving Test Results

This question sought to determine how the sample from the experimental group performed on the delayed mathematics problem-solving skills test in comparison to the results of the immediate post-test. In addressing this question, the means and standard deviations of the experimental group's scores on both the immediate and delayed tests were computed. These results are summarized in Table 4:

Table 4: **T-Test Results between the Immediate and Delayed Applications among Experimental Group**

Variable	Application	No.	Mean	St. dv.	T-Value	Sig.
Mathematical Problem-Solving Skills Test	Immediate	61	37.49	1.04	0.940	0.079
	Delayed	61	38.01	0.98		

Table 4 summarizes the performance comparison in problem-solving skills test of the experimental group with respect to the application of immediate and delayed instructions through a t-test. From this table it is clear that the performance in the immediate application had an average of 37.49 with a standard deviation of 1.04. In the delayed application the performance was slightly higher, with the group achieving an average of 38.01 with a standard deviation of 0.98.

From the results, the computed t-value turned out to be 0.940: this value is very low, indicating that the difference between the scores in immediate application and delayed application is not substantial. Also, the significance value (Sig.) was 0.079, thus greater than the conventional significant level of 0.05; hence the difference between the two applications can be regarded as insignificant. Therefore, these findings tend to suggest that the performance in the delayed test did not improve significantly over the immediate test, which may account for the retention of the performance level in mathematical problem-solving skills.

Notably, these findings can be analyzed considering some aspects that suggest some learning gains through digital games, especially as relate to acquired skills retention. While the difference between immediate and delayed application was not statistically substantial, scores on the delayed test still differed somewhat from the scores in immediate application. This implies that the skills developed during the training were retained to a certain extent. The skills retention is an indication of the positive effects of digital game-based instruction in solving mathematical problems.

This type of learning has the advantage of easier skill retention over an extended period, which explains the relative stability in performance between the two applications. The positive impact of digital games is not limited to improving skill performance at a particular point in time but rather includes the enhancement of skill performance at different times. Thus, these results strongly emphasize that educational devices are useful in the development of retention skills, which is the reason for significant concern in instructional technology.

6. Discussion

6.1 Discussion the Findings of Problem-Solving Test

The analysis conducted in this study suggests that both the pre-test results and the teaching strategy used in this study had a significant impact on the students' performance in mathematical problem-solving. The students' test scores from the pre-test were powerful determinants of the scores of the post-test. However, they achieved better scores due to the impact of the teaching strategy used to a progressive degree.

This can be viewed from a psychological aspect as the outcome can be explained using constructivist theory which foregrounds prior knowledge. In both Piaget's and Vygotsky's understanding, learners seek to construct new knowledge from new information in relation to their existing knowledge structure. In this research study, the students who had stronger pre-existing understanding were able to benefit more from the new strategy because they already possessed adequate knowledge that enabled them to interact with the new information. The students were more ready to deal with the new method of instruction after undergoing the pre-test which measured their existing level of knowledge. This evidence also complements previous research in constructivism, which motivationally argues the necessity of a starting point for basic learning. Al Khateeb (2019) and Hussein et al. (2022) also proved this claim, namely that students who have a solid foundation are more likely to become successful when advanced teaching methodologies are applied, resulting in better post-test scores.

Although the prior knowledge factor is clear, the most important factor is the teaching strategy that was employed. Game-based methods have been found to be more effective in improving students' performance in aspects of mathematical problem solving than other teaching and learning methods. This is explicable in the light of constructivist learning theory which supports active, interactive, and student-centered methods of teaching and learning. In the case of digital games, learners find themselves in a context where they extract meaning from the learning material in a lively way. This supports Vygotsky's learning scaffolding where learners are challenged to perform tasks that are slightly beyond their reach but achievable through the right support. The games in this study supported students by challenging them and giving them immediate feedback and more complex tasks to solve as well as assisting their cognitive development and problem-solving skills.

Similar to previous studies, this research highlights the effectiveness of digital games in improving cognitive skills. Sugianto (2023), for instance, noted the immense value of digital games in enhancing critical thinking and problem-solving skills among students which positively impact their grades. From the constructivist perspective, games serve as a means to achieve cognitive apprenticeship where students learn a variety of problem-solving methods through practice in an enabling environment.

The analysis revealed that digital games can enhance a range of cognitive skills, including speed of thinking, confidence and effective problem solving. This is consistent with Piaget's stages of cognitive development which asserts that logical and problem-solving skills can be cultivated through hands-on activities such as playing games. As Kermani (2017) reported, student learning is improved by the introduction of digital games since students are now able to think faster and tackle problems more competently. It is reasonable to draw the conclusion that digital games are a critical educational method that aids in the development of invaluable cognitive and problem-solving skills.

For this reason, the use of digital games in the teaching and learning of mathematics, using constructivist theory as the basis for integration, is an approach that is highly effective in developing students' skills in problem solving. Through games, students can learn in an interactive environment, where a variety of strategies can be tried out, and feedback is provided immediately so that skills can be developed gradually. In this regard, mathematics education is made entertaining to the learner while at the same time, their skills towards reasoning and problem-solving in mathematics are enhanced. This is consistent with the view that students build their knowledge actively and through the work that they have to do, which is clearly constructivist (Barros et al., 2022; Baul & Mahmud, 2021; Deng et al., 2020).

6.2 Discussion the Findings of Delayed Problem-Solving Test

The findings of the delayed problem-solving test showed that the participants performed it as well as the immediate test score. This is not surprising because of how well they retained skills. Even if no significant difference had been shown in the statistical data gathered, it is interesting to note that the digital games used enhanced the retention of problem-solving skills in mathematics.

This can be elucidated by the characteristics of digital games that offer an interactive and productive environment for learning. According to Sweller (2011), "cognitive load theory" states that games are developed in a manner that makes them more interesting by offering tasks of an appropriate level of difficulty to optimize the processes of information processing and memory recovery. Moreover, digital games also foster cognitive apprenticeship (AlAli et al., 2025; Bani Irshid et al., 2023; Fraihat et al., 2022) by providing students with the opportunity to engage in problem-solving activities in realistic and vibrant settings. This facilitates greater learning.

The similarities between immediate and delayed measures of retention may also be explained by the cognitive skills developed such as working memory, attention, and executive functions. Digital games improve these abilities by asking players to take action and retain information while solving problems. This is consistent with Al Khateeb's (2019) theory of working memory, which claims that the processes of solving complex tasks are of primary concern.

Moreover, the principle of interactive repetition embedded in digital games allows students to face similar tasks and challenges which enhance the retention of problem-solving skills. Bani Irshid et al. (2023) advocate for reinforcing the skills by following the spaced learning principle which states strategic intervals should be set for revisiting the learned material in order to build stronger memories.

Retention will also be aided by the aspect of motivation of the digital game. The games create a space and an appealing atmosphere that significantly rewards the students for their efforts. As is noted in self-determination theory, such motivation helps students engage even in the absence of external factors, which in turn increases retention. These outcomes agree with other studies, such as those of Papadakis et al. (2018) who claimed that students learn best using games. Anderson and Bavelier (2011) also showed that working memory and other functions of digital games tend to enhance more complex cognitive functions, which are vital to problem solving.

7. Conclusions

This study shows how effective a modern approach can be integrated with older ones focusing on digital games to teach mathematics effectively. The use of modern tools, such as interactive ones, not only improves student performance in the immediate term but also ensures the retention of skills learned in the long run. The findings suggest that for practice, games are not only an effective means in aiding the development of cognitive skills, but also skill retention over a period of time as well. This makes them significant for aiding learning in children as it extends beyond the classroom and supports ongoing retention.

On the instructional aspect, the research highlights the concern regarding the adoption of digital games within mathematics education towards enhanced critical thinking and problem-solving competencies. Teachers should support this as active participation among learners is enhanced while at the same time, essential concepts in mathematics are reinforced. For the policymakers and curriculum developers, this study recommends the need to include game-based learning in the intended curriculum and its adoption in schools. Moreover, pre-tests would stand as an initial measure of students' knowledge and other chapters can be personalized to fit their need, thereby improving the overall learning experience.

Every study comes with its own constraints, and this study does as well. The sample in consideration was taken from private schools in Amman, which greatly limits the broad applicability of the findings of this study to other students in other regions and educational contexts. It may not adequately represent people of a particular socioeconomic status or an environment different from the one in which they grew up. Also, this study was conducted on the basis of one test taken by the students for assessing their mathematical problem-solving abilities and it may not have included a large portion of the students' capabilities. This is another instance where future effort should be focused on ensuring different participant samples and the use of innovation in assessment techniques that touch on the effects of digital games on learning mathematics in order to overcome these constraints.

In addition, the use of immediate and delayed test scores in the study, as mentioned previously, does not allow much evaluation of the retained information long after the delayed test phase. Follow-up studies can be conducted to examine the impact of game-based learning on retention over an extended period of time to determine the level of cognitive growth this instructional strategy can foster. One more important area that needs to be researched further is the effect, if any, of DGBL on students' learning, especially the possible adverse effects related to the people overusing technology or any disadvantages stemming from lack of proper motivation to learn in a non-technological setting.

To summarize, although the present study shows the enhancement by digital games on one's ability to solve mathematics problems and their retention, the limitations seek to be addressed for further research in this area. In order to enhance the understanding of how these games can be used in an educational context, future studies should broaden their scope and include different demographics, the effects of other forms of digital games, and possibly even negative repercussions. This would greatly aid in improving pedagogical practices as well as the utilization of digital games in achieving positive educational attainment and fostering sustained cognitive development.

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