# Serious Digital Games: Enhancing Mathematical Performance and Motivation in Students with Developmental Dyscalculia

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**ABSTRACT:**

This research investigates the impact of digital math serious educational games (SEGs) on improving math skills and motivation among sixth-grade students, with a particular focus on first-degree equations, and a specific emphasis on students with developmental dyscalculia. A comparative study was conducted between two groups: one comprising 52 students who engaged with the digital math SEG "Battleship," and another group of 52 students who utilized the traditional curriculum textbook.

The study's objectives were to assess the effectiveness of digital math SEGs in enhancing mathematical performance and to evaluate the motivation levels of students with Developmental Dyscalculia (DD). The assessment tool included a test on first-degree equations and the Motivated Strategies for Learning Questionnaire (MSLQ). This study innovatively integrates Constructivist Learning Theory and Self-Determination Theory to design and evaluate the impact of digital math SEGs on performance and motivation.

Results revealed that students using the digital math SEG significantly improved their performance compared to those using the textbook. Although the textbook group reported slightly higher motivation, the difference in motivation between the two groups was not statistically significant, highlighting the complexity of motivational factors for students with Developmental Dyscalculia.

*Keywords:* Serious Educational Games (SEGs), Developmental Dyscalculia, Mathematical Performance, Motivation in Learning, Constructivist and Self-Determination Theory

## INTRODUCTION

In recent years, the integration of digital serious educational games (SEGs) in elementary education has garnered significant attention as an innovative strategy to enhance student learning and motivation, particularly in challenging subjects such as mathematics. SEGs merge gameplay elements with educational content. In doing so, they create engaging and interactive environments that foster deeper learning experiences (Ghanbaripour et al., 2024; Zainuddin et al., 2020). This approach is particularly beneficial for students with learning disabilities, such as DD, who struggle with numerical and arithmetical concepts and thrive in adaptive learning contexts (Castaldi et al., 2020; Jadán-Guerrero et al., 2021).

Research consistently demonstrates that SEGs can substantially enhance student engagement and motivation, providing real-time feedback and personalized learning pathways that are often absent in traditional teaching methods (Hwang et al., 2017; Zainuddin et al., 2020). For instance, Jadán-Guerrero et al. (2021) highlight how the interactive nature of SEGs transforms passive learning into active participation, enabling students to grasp complex concepts more effectively. This is particularly crucial in mathematics, where SEGs have been shown to improve performance in arithmetic tasks (Altundağ & Uzunaslan, 2023).

Moreover, the ability of SEGs to cater to individual learning needs through personalized feedback mechanisms has emerged as a key factor in their efficacy (Hwang et al., 2017; Yu et al., 2021). Studies indicate that well-designed educational games can enhance both intrinsic and extrinsic motivation, leading to improved academic outcomes for students with Down syndrome (Dowker, 2024). The incorporation of gamification elements—such as points, rewards, and progression systems—has also been linked to improved retention of mathematical concepts and increased student engagement (Partovi & Razavi, 2019).

However, successful implementation of SEGs in educational settings requires careful alignment with curriculum objectives and an understanding of students' diverse needs (Altundağ & Uzunaslan, 2023; Zainuddin et al., 2020). Poorly designed games that do not align with learning goals may lead to disengagement and frustration, particularly for students with special learning needs (Kucian & von Aster, 2015). Therefore, it is vital to develop targeted interventions that are both pedagogically sound and tailored to individual cognitive profiles (Castaldi et al., 2020).

Overall, the expanding body of research underscores the potential of SEGs to transform elementary mathematics education, particularly for students with DD, by providing personalized, motivating, and compelling learning experiences (Hwang et al., 2017; Zainuddin et al., 2020). For students with DD, these motivational boosts can be crucial for overcoming learning barriers and achieving better educational outcomes (Siadaty et al., 2016).

### The Problem and the Need for the Research

There is a deficiency in a thorough summary of empirical evidence regarding the effectiveness of gamification in K-12 education (Dehghanzadeh et al., 2023).

DD affects 2-6% of the population, posing significant challenges in math education for affected students. This learning disability impairs basic numeric and arithmetic understanding despite normal intelligence and education and can substantially impact daily life, both personally and professionally (Castaldi et al., 2020). Cognitive deficits, including issues with attention, memory, and specific numeric skills, characterize the condition.

Despite the prevalence of DD, educators face a critical gap in readily accessible, evidence-based interventions. The lack of adequate resources highlights the need for intensified research efforts to develop targeted solutions (Holman, 2023). In particular, there is a notable scarcity of research specifically addressing the effectiveness of digital serious educational games (SEGs) in enhancing math performance and motivation for students with DD.

### Contribution to the Field

This research will contribute to the growing body of evidence on the effectiveness of digital math SEGs in learning mathematics, especially for students with DD. Specifically, it investigated whether digital math SEGs can enhance the acquisition of knowledge, skills, and motivation in mathematics among sixth graders with DD, with a focus on first-degree equations. This will be tested by comparing a group of students with DD who practiced with the digital math SEG "Battleship" to a group of students who studied the typical curriculum textbook.

### Purpose, Objectives, and Research Questions

#### *Main Purpose*

This research aims to address the gap in knowledge by exploring the potential of serious digital games as a tool to enhance both performance and motivation in math education for students with DD. Specifically, the study examines whether digital math SEGs contribute to the acquisition of knowledge, skills, and motivation in mathematics among sixth graders with DD, focusing on first-degree equations.

### *Objectives*

The main objective of this research was to examine how digital math SEGs impact the math performance and motivation of sixth-grade students (12 years old) with DD.

The two specific objectives were:

- To determine whether digital math SEGs improve math performance for students with DD.
- To examine students' motivation, particularly focusing on those with DD.

### Research Questions

- Does the use of digital math SEGs improve math performance in first-degree equations among sixth graders with DD compared to traditional textbook methods?
- How does the use of digital math SEGs affect the motivation of sixth graders with DD in mathematics compared to traditional textbook methods?

## LITERATURE REVIEW

### The Role of Gamification in Enhancing Motivation and Learning

Games play an essential role in human culture and society, fostering motivation and engagement (Bozkurt & Durak, 2018). This is why game mechanics are increasingly being applied in traditionally non-gaming environments, such as primary and secondary education (e.g., Ioannou, 2019; Zainuddin, 2018).

Gamification refers to the application of game elements in non-game settings (Deterding et al., 2011) and is associated with various effects on emotions and motivation (Koivisto & Hamari, 2019), as well as on behavior, including academic performance and engagement (Putz et al., 2020).

Additionally, gamification can influence cognitive learning outcomes (Vlachopoulos & Makri, 2017; Zhang et al., 2022). The study by Li et al. (2023) highlights the positive impact of gamification on learning outcomes, with an overall effect size of 0.822, suggesting it may be an effective method for enhancing teaching and learning across various educational settings. Moreover, factors such as educational level have been found to influence the effectiveness of gamification, with primary school students demonstrating the greatest effect, which aligns with the research of Lei et al. (2022).

However, the findings regarding these impacts can sometimes be inconsistent (Sailer & Homner, 2020), particularly in determining whether gamification enhances intrinsic motivation over extrinsic motivation (Mekler et al., 2017). Thus, gamification is not inherently effective (Sailer et al., 2017). Instead, designing successful gamified interventions—such as serious games and game-based learning—requires a theoretical understanding of the cognitive, emotional, and motivational mechanisms that drive the effects of gamification (Koivisto & Hamari, 2019; Sailer & Homner, 2020).

### Effects and Challenges of Gamification

The effects of gamification in education are multifaceted and have garnered significant attention in recent years. Research consistently demonstrates that gamified learning experiences can lead to enhanced motivation, increased engagement, and improved academic performance among students. Partovi and Razavi (2019) highlight the significant impact of game-based learning on academic motivation, revealing that students who engage with educational games exhibit higher levels of motivation and performance compared to those in traditional learning environments. This assertion is supported by numerous studies that indicate gamification can transform passive learning into active participation, fostering a sense of ownership and agency among students (Vankúš, 2021).

Gamification encourages a more interactive learning experience, where students are not merely recipients of information but active participants in the learning process. The incorporation of game elements, such as points, levels, and rewards, creates a competitive yet supportive atmosphere that motivates students to strive for excellence. However, while gamification offers numerous benefits, it is not without its challenges. One major concern is the potential for superficial engagement, where students may become overly focused on earning rewards rather than on the intrinsic value of learning itself. This phenomenon, known as "reward-centric" behavior, can undermine the educational purpose of gamification if not carefully managed (Schrader, 2023).

Additionally, the effectiveness of gamification is contingent upon thoughtful integration into the curriculum. Yu et al. (2021) found that the impact of educational games on learning outcomes heavily relies on how well these tools align with educational objectives. For instance, poorly designed games that fail to address learning goals effectively may lead to disengagement or confusion among students. Mixed results from various studies indicate the need for continuous improvement in game design and its alignment with students' individual learning needs (Altundağ & Uzunaslan, 2023). This alignment is crucial, as it ensures that the gamified elements serve to enhance the educational experience rather than distract from it.

Moreover, it is essential to consider the diverse backgrounds and experiences of students when implementing gamification strategies. Some students may thrive in a gamified environment, while others may find it overwhelming or intimidating. Research by Dowker (2024) underscores the importance of recognizing individual differences in motivation and learning styles, advocating for personalized approaches to gamification that cater to these variations. By incorporating adaptive learning technologies and feedback mechanisms, educators can create more inclusive gamified experiences that support the diverse needs of their students.

**DD and Serious Educational Games**

DD is a specific learning disability that significantly impacts a child's ability to understand and perform mathematical tasks. Characterized by a heterogeneous profile, students with DD often struggle with basic numerical and arithmetic skills despite possessing average or above-average intelligence and educational opportunities. The prevalence of DD in the general population is estimated to range from 3% to 7%, with difficulties that can persist into adulthood if not adequately addressed through targeted interventions (Castaldi et al., 2020).

The theoretical foundations of educational games provide essential insights into their potential impact on students with DD. Plass et al. (2020) offer a comprehensive discussion on the theoretical underpinnings of serious games and game-based learning, explaining how these tools facilitate knowledge acquisition, practice, and the development of essential learning and innovation skills. This theoretical framework is vital for understanding the pedagogical value of serious educational games (SEGs) in addressing the cognitive deficits associated with DD. Schrader (2023) further explores the role of SEGs in promoting cognitive outcomes, highlighting their positive impact on learner motivation and engagement. This is echoed by the findings of Zainuddin et al. (2020), who demonstrated how game-based learning environments improve students' academic performance and motivation in mathematics.

As global trends in gamification for students with disabilities continue to evolve, there is increasing recognition of the potential benefits of SEGs. Research by Jadán-Guerrero et al. (2023) highlights a growing acceptance of gamification as a pedagogical approach, revealing a geographical concentration of studies in Europe and emphasizing the influence of journals such as *Computers and Education* (Elsevier) in advancing the discourse around game-based learning. These trends suggest that gamification, when designed effectively, can cater to diverse educational contexts and provide significant support to students with learning disabilities.

In relation to DD, Castaldi et al. (2020) provide critical insights into the cognitive deficits that hinder basic numerical and arithmetic skill development. They emphasize that DD encompasses various cognitive processes involved in mathematical problem-solving, highlighting the necessity for targeted interventions that address these specific challenges. Dowker (2024) elaborates on the relationship between DD and individual differences in mathematical abilities, reinforcing the need for personalized educational technologies that can cater to the diverse profiles of students with DD. The "Mathlete" adaptive assistive technology tool introduced by Dhingra et al. (2024) exemplifies the Concrete–Representational–Abstract (CRA) instructional approach, emphasizing structured interventions that can significantly benefit students facing DD.

Motivation and engagement are pivotal factors influencing academic performance, especially when utilizing digital learning tools. The works of Partovi and Razavi (2019) underscore the substantial impact of game-based learning on academic motivation, showing that students who engage with educational games demonstrate higher levels of motivation and improved performance compared to those in traditional learning environments. This finding is supported by Yu et al. (2021), who conducted a study on the effects of educational games on learning outcomes, revealing that while these tools boost motivation and engagement, their effectiveness depends on how well they are integrated into the curriculum. Vankúš (2021), in a systematic review of game-based learning in mathematics education, concludes that game-based learning can have positive influences on students' motivation and affective experiences. However, some studies report mixed results, indicating that future research must focus on improving game design and better aligning it with students' individual learning needs.

The role of educational technologies in supporting students with special learning needs is critical to current research. Avila-Pesantez et al. (2019) discuss the use of augmented reality (AR) serious games to support children with DD, illustrating how game-based interventions can help students transfer mathematical concepts from abstract learning to real-world contexts. This aligns with research focus on digital educational games as tools for improving fraction comprehension in students with DD. Similarly, Kohn et al. (2020) emphasize the importance of structured, computer-based learning programs for children with DD. Their study on the Calcularis program showed that adaptive and targeted interventions could effectively improve numerical cognition in children with learning difficulties, which aligns with own research on the benefits of digital learning tools. These findings are supported by Altundağ and Uzunaslan (2023), who found that digital games designed with life-based practices help students with DD better transfer mathematical concepts into daily life, enhancing their motivation and retention of knowledge.

## METHOD AND MATERIALS

### Research Type and Justification

This study adopts an empirical research design, focusing on the comparative effectiveness of digital serious educational games (SEGs) versus traditional textbook methods in enhancing mathematical skills and motivation among students with DD. Empirical research, characterized by direct or indirect observation and measurement of phenomena, allows for the assessment of real-world educational interventions and their impacts (Creswell, 2014). The choice of an empirical approach is supported by its ability to provide concrete evidence on the effectiveness of different teaching methods and tools. For instance, empirical studies have demonstrated that digital games can significantly improve learning outcomes by offering interactive and adaptive learning experiences (Papastergiou, 2009; Becker, 2010). By comparing the performance and motivation of students using a digital SEG with those using traditional methods, this research aims to generate actionable insights into how educational technologies can support students with DD.

### Theoretical Models

#### *Theoretical Framework*

This research is grounded in two primary theoretical models: Constructivist Learning Theory and Self-Determination Theory (SDT). These models provide the framework for understanding how digital math serious educational games (SEGs) can enhance mathematical performance and motivation among students with learning difficulties.

*Constructivist Learning Theory*

Constructivist Learning Theory posits that learners construct their own understanding and knowledge through experiences and reflection on those experiences. Key aspects include:

- Active Learning: Engaging students in activities that require them to participate in their learning process actively.
- Scaffolding: Providing support to students as they develop new skills and knowledge.
- Social Interaction: Encouraging collaboration and discussion among peers to enhance learning.

*Self-Determination Theory (SDT)*

SDT emphasizes the role of motivation in human behavior, focusing on three basic psychological needs.

- Autonomy: Feeling in control of one's own actions and decisions.
- Competence: Feeling effective and capable of achieving desired outcomes.
- Relatedness: Feeling connected and valued by others.

*Integration of Theoretical Models*

The study integrates Constructivist Learning Theory and Self-Determination Theory to explore how digital math SEGs can enhance mathematical performance and motivation. The digital game "Battleship" incorporates elements of both theories (Table 1).

- Constructivist Elements: Provides an interactive environment where students actively engage in solving equations, receive immediate feedback, and collaborate with peers.
- SDT Elements: Fosters a sense of autonomy (choice in problem-solving strategies), competence (progressive difficulty levels and rewards), and relatedness (collaborative tasks and peer support).

By combining these theoretical models, the study aimed to create a learning environment that improves both mathematical performance and motivation, specifically catering to students with DD. The "Battleship" game was designed to leverage principles of active learning, scaffolding, autonomy, competence, and relatedness, thus providing a holistic and engaging learning experience.

### Participants

The study involved 104 sixth-grade students, approximately 11 to 12 years old, from seven state-funded schools in Attica sector in Greece. Participants were randomly selected from a pool of ten elementary schools that had

Table 1. **Application of Theoretical Models in the Study**

| Theoretical Model | Key Elements | Application in Research | Implementation in Digital Math SEG "Battleship" |
|---|---|---|---|
| Constructivist Learning Theory | Active Learning | Students engaged in solving math problems interactively | Interactive math problems requiring active student participation |
| | Scaffolding | Support provided through guided problem-solving | Hints and feedback mechanisms to guide students |
| | Social Interaction | Collaboration among students encouraged | Multiplayer modes and discussion forums within the game |
| Self-Determination Theory (SDT) | Autonomy | Opportunities for students to choose problem-solving methods | Various strategies allowed for solving equations |
| | Competence | Challenges matched to skill level with rewards for progress | Progressive difficulty levels and badges for achievements |
| | Relatedness | Emphasis on peer support and connection | Cooperative gameplay and team-based tasks |

positively responded to the researchers' request through the Department of Primary Education. The sample was evenly divided into two groups: an experimental group (n = 52), referred to as the Game-group, and a control group (n = 52), referred to as the Text-group. Both groups had a similar gender distribution, with 46% boys and 54% girls in the experimental SEG group, and 48% boys and 52% girls in the control textbook group.

A purposive sampling method was used to gather data exclusively from students with DD. Although random assignment was applied between groups, the initial sample consisted only of students already diagnosed with DD through certified public diagnostic centers. This procedure ensured the internal validity of the study. The targeted sampling approach aimed to select a specific population efficiently, students with DD, rather than achieve proportional representation (Anaekwe, 2007).

All participants and their guardians provided informed consent before the commencement of the study. The research was designed to ensure the privacy, confidentiality, and safety of all participants.

**Sample Size and Power Calculation**

The following parameters were used to calculate the sample size and assess the statistical power.

- Significance level (α): 0.05
- Statistical power: 0.80 (or 80%)
- Effect size (Cohen's d): 0.5 (medium effect size)

A significance level of 0.05 means there is a 5% chance of rejecting the null hypothesis when it is actually true, with a critical Z-value of 1.96 (from standard Z-tables). The statistical power was set at 0.80, providing an 80% probability of detecting a real effect if it exists, corresponding to a Z-value of 0.84.

The required sample size was calculated using the following formula for a two-sample t-test:

$$n = \left(\frac{Z\ \alpha/2 + Z\beta}{\Delta/\sigma}\right)^2 = \left(\frac{1.96+0.84}{0.5}\right)^2 = 5.6\ ^2 = 31.36$$

This gives 31.36 for each group, so for a two-group comparison, the total sample size is 2×31.36=62.722. Rounding 62.72 gives approximately 63 participants. Therefore, the required sample size for a two-group comparison is 64 participants (if rounded up slightly for safety). Since the study ultimately included 104 students (52 in each group), the actual sample size significantly exceeded the minimum requirement. This larger sample size enhanced the statistical power of the study, further increasing the likelihood of detecting significant effects if they existed.

This calculation demonstrated that the study has sufficient power to detect meaningful differences, aligning with Cohen's (1988) guidelines for effect size and sample size considerations. These recommendations are further validated by subsequent research (e.g., Butterworth & Kovas, 2013). Notably, the sample size calculation was conducted a priori to ensure adequate statistical power. The actual sample (n = 104) exceeded the minimum requirement of 64 participants, thereby increasing the statistical power beyond the conventional threshold of 0.80 and further enhancing the reliability of the findings.

## Materials

### *Digital Serious Educational Game*

The digital game utilized in this study was "Battleship," a free online educational tool developed by Quia, USA (https://www.quia.com/ba/24940.html). The game focuses on solving first-degree equations and includes three levels of difficulty. Players interact with the game by selecting squares on a grid to locate enemy ships and solve equations that appear upon hitting a ship. Correct answers result in an explosion, while incorrect answers display a target. This process continues until all ships are sunk.

### *Textbook Materials*

The control group used traditional curriculum textbook methods to study first-degree equations. The textbook provided similar content to that covered in the game but lacked interactive features.

### *Instruments*

Table 2 shows the questionnaires used to assess performance and motivation. Performance was assessed through common exercises in the curriculum textbook, while motivation was assessed through the "motivational beliefs" section of the Motivated Strategies for Learning Questionnaire (MSLQ).

## Procedure

The study lasted 12 weeks, with sessions held four times per week after the regular school day in the respective schools' labs. Research suggests that computer-based training should be conducted for a minimum period of 3 months, with a frequency of 3 to 4 sessions per week (e.g., Käser et al., 2013; Kohn et al., 2020).

Table 2. **Overview of Instruments**

| Instrument | Description | Items/Questions |
|---|---|---|
| **Mathematical Performance Test** | Assessment of understanding of first-degree equations. Includes 12 equations and related problems. | A. Solve the following equations:<br>1. 5x = 10<br>2. 4 = 2x<br>3. 4x + 2 + 3x = 9<br>4. -8x - 2x - 3 = 7<br>5. x/5 = 3<br>6. x/2 - 11/2 = 0<br>7. 5x + 2 = -6 - 3x<br>8. x + 2 = 2x + 1<br>9. -5x - 7 = -5x + 10<br>10. x + 4 = 2x + 4<br>11. x/5 = 3/9<br>12. x/2 - 10/3 = 0<br><br>B. Determine which equations express the same mathematical relationship as 3x = 9 (without solving):<br>1. x = 3<br>2. x = 9 – 3<br>3. 6x = 18<br>4. 7x = 8<br>5. x = 9/3<br>6. x = 9 + 3<br>7. x/2 = 9/2<br>8. 9 = 5 + 3x<br>9. 9 + 8 = 3x + 8<br>10. 3x - 10 = 9 – 10<br>11. 3x - 6 = 3<br>2. 3x - 1 = 9 - 1 |
| **Motivation Assessment** | "Motivational beliefs" section of the Motivated Strategies for Learning Questionnaire (MSLQ) to assess student motivation. | 1. I believe I will receive a good grade in this course.<br>2. I am confident I can do well in mathematics.<br>3. I enjoy solving mathematical problems.<br>4. I feel motivated to learn mathematics because it is interesting.<br>5. I am able to understand complex mathematical concepts. |

Both the experimental group, which engaged with the *Battleship* game alongside the curriculum textbook material, and the control group, which studied only the textbook material, completed performance and motivation tests. Randomization ensured that students' prior experiences with games or their mathematical performance did not bias the results.

To ensure comparable prior mathematical performance between the two groups, the students' scores from their school's first-semester assessment were reviewed. This evaluation enabled an accurate baseline comparison, ensuring that any differences in performance could be attributed to the intervention rather than pre-existing disparities. Additionally, prior gaming experience was assessed to confirm that both groups had low levels of gaming exposure. Students were considered to have "low" gaming experience if they engaged in gaming less than three times a week and spent less than two hours per day on such activities, aligning with definitions used in international literature (Gentile, 2009; Vasalou et al., 2008; Lemmens et al., 2011).

**Data Analysis**

Data from the performance test and motivation assessment were analyzed using SPSS statistical software (v.21) and numerical calculations in Excel 10. Assumptions of normality (Shapiro–Wilk test) and homogeneity of variances (Levene's test) were checked and met before conducting the analyses. The analysis aimed to evaluate differences in mathematical performance and motivation between the experimental and control groups. For both tests, the mean value for each student was calculated.

## RESULTS

Before conducting the independent samples t-test and the mixed-design ANOVA, the assumptions of normality and homogeneity of variance were examined. Shapiro–Wilk tests indicated that the data did not significantly deviate from normality for either the experimental group ($W = 0.98$, $p = .34$) or the control group ($W = 0.97$, $p = .21$). Levene's test confirmed the homogeneity of variances across groups, $F(1, 102) = 1.12$, $p = .29$. Therefore, the assumptions for parametric testing were met, and the subsequent analyses were considered valid.

**Mathematical Performance**

To evaluate differences in students' mathematical performance, an independent samples t-test was conducted on the post-test scores between the experimental group (students using the "Battleship" digital game and the curriculum textbook) and the control group (students using only the curriculum textbook). The results revealed that the experimental group (M = 85.20, SD = 10.45) scored significantly higher than the control group (M = 72.35, SD = 12.60), $t(102) = 5.63$, $p < .001$, 95% CI [8.33, 17.37], indicating a statistically significant difference in favor of the digital game (Table 3). The effect size was large (Cohen's d = 1.10, 95% CI [0.66, 1.52]), suggesting that the use of the digital game had a substantial positive impact on students' ability to solve first-degree equations. According to Cohen's (1988) benchmarks, values above 0.80 represent large effects, which in educational research indicate that the intervention produced not only statistically significant but also practically meaningful improvements. In this context, a Cohen's d of 1.10 implies that the average student in the game-based group outperformed approximately 86% of the students in the control group. This demonstrates that the digital math game "Battleship" was highly effective in supporting mathematical learning for students with DD.

The results show that students who used the "Battleship" game to learn first-degree equations performed significantly better than those who used the traditional textbook method.

**Motivation**

To analyze differences in motivation, a 2x2 mixed-design ANOVA was performed, with time (pre-test vs. post-test) as a within-subjects factor and group (experimental vs. control) as a between-subjects factor. There was a significant main effect of time, $F(1, 102) = 23.85$, $p < .001$, $\eta^2 = .19$, *indicating that motivation levels increased for both groups from pre-test to post-test. However, the interac-*

Table 3. **Means, Standard Deviations, and Independent Samples t-Test Results for Post-Test Scores**

| Group | M | SD | t(102) | p | Cohen's d | 95% CI (Mean Difference) | 95% CI (d) |
|---|---|---|---|---|---|---|---|
| Experimental | 85.20 | 10.45 | 5.63 | 0.003* | 1.10 | [8.33, 17.37] | [0.66, 1.52] |
| Control | 72.35 | 12.60 | | | | | |

**p< .01.*

Table 4. **ANOVA results for motivation**

| Measure | Experimental Group | | Control Group | | F(1, 102) | p | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | | | |
| Motivation Pre-Test | 3.20 | 0.60 | 3.25 | 0.58 | | | |
| Motivation Post-Test | 3.55 | 0.65 | 3.60 | 0.62 | 23.85 | <.001 | 0.19 |
| Time × Group | | | | | 2.43 | 0.19 | 0.02 |

*tion between time and group was not statistically significant, F(1, 102) = 2.43, p = .19,* $\eta^2 = .02$*, suggesting that the increase in motivation was similar across the experimental and control groups. Descriptive statistics revealed that motivation scores were slightly higher in the control group after the intervention (M = 3.60, SD = 0.62, 95% CI [3.45, 3.75]) compared to the experimental group (M = 3.55, SD = 0.65, 95% CI [3.40, 3.70]). However, these differences were not statistically significant.*

In summary, although students in both groups demonstrated increased motivation after the intervention, the absence of a significant interaction effect indicates that the digital game was not more effective than traditional methods. This suggests that motivational gains may rely more on task design and individual learner characteristics than on the mere presence of gamified elements.

## DISCUSSION

### Educational implications

Taken together, the findings suggest that serious digital games can be a highly effective tool for improving mathematical performance among students with DD, but their impact on motivation may be more limited. This dual outcome has important implications: teachers may confidently adopt such games to strengthen cognitive outcomes, while recognizing that motivational benefits are not guaranteed without careful instructional design. Embedding adaptive challenges, personalized feedback, and cooperative elements could potentially enhance motivational gains in future implementations (Plass et al., 2020).

### Impact of Digital Math SEGs on Mathematical Performance

The results demonstrate a significant improvement in mathematical performance among students using the "Battleship" digital game compared to those using traditional textbook methods. Specifically, the experimental group (M = 85.20, SD = 10.45) outperformed the control group (M = 72.35, SD = 12.60) with a statistically significant difference ($t(102) = 5.63$, $p < .001$). This aligns with existing literature suggesting that digital serious educational games (SEGs) can enhance understanding and performance in mathematics, particularly for students with DD. As highlighted by Ghanbaripour et al. (2024) and Zainuddin et al. (2020), the interactive and engaging nature of SEGs fosters a more active learning environment that can significantly aid in comprehending complex concepts, such as first-degree equations. The large effect size (Cohen's d = 1.10) further emphasizes the substantial positive impact of the digital game on students' abilities, corroborating the findings of Plass et al. (2020) regarding the effectiveness of gamification in educational contexts. This aligns with existing literature suggesting that digital serious educational games (SEGs) and gamification can enhance mathematical learning outcomes, as highlighted by Sanchez et al. (2020) in their study on gamified quizzes, and more recently by Polydoros and Antoniou (2025), who emphasized the specific potential of SEGs for students with learning disabilities.

### Effects of Digital Math SEGs on Motivation

While the study indicates that both the experimental and control groups experienced an increase in motivation from pre-test to post-test ($F(1, 102) = 23.85$, $p < .001$, $\eta^2 = .19$**), the lack of a statistically significant interaction between time and group (**$F(1, 102) = 2.43$, $p = .19$) suggests that the increase in motivation was similar across both groups. This finding aligns with some of the mixed results reported in the literature regarding the influence of gamification on motivation (Hwang et al., 2017; Mekler et al., 2017). The slight difference in motivation scores, with the control group exhibiting a marginally higher increase, could point to the possibility of reward-centric behavior, as discussed by Schrader (2023), where students may focus more on the intrinsic value of learning when not immersed in gamified environments. Therefore, while digital math SEGs positively influence engagement and motivation, their impact may depend on the careful integration of gamification elements within the educational framework.

A critical interpretation of these findings suggests that gamification, when implemented without sufficient alignment to learners' psychological needs (e.g., autonomy, competence, and relatedness; Deci & Ryan, 2000), may not yield sustained motivational benefits. In this respect, the present results raise questions about whether the motivational outcomes attributed to SEGs are inherent to the digital medium or contingent upon broader instructional and contextual factors. This indicates a need for future studies to disentangle the relative contributions of game mechanics, instructional design, and individual learner characteristics in shaping motivational trajectories.

## CONCLUSION

The findings of this study provide compelling evidence for the effectiveness of digital serious educational games (SEGs), specifically the "Battleship" game, in enhancing mathematical performance among sixth-grade students with DD. The significant improvement in post-test scores of the experimental group indicates that gamified learning experiences can be highly beneficial in helping students grasp complex mathematical concepts, such as first-degree equations.

Furthermore, the analysis of motivation levels revealed that while both groups experienced an increase in motivation from the pre-test to the post-test, the absence of a significant interaction effect suggests that traditional methods can still effectively foster motivation. However, the slight advantage observed in the control group highlights the necessity for careful consideration of how gamification elements are integrated into educational contexts, as inadequately designed games may not resonate with all learners.

Overall, the study reinforces the potential of SEGs to transform mathematics education for students with DD by providing personalized, motivating, and compelling learning experiences. It calls for educators to embrace innovative pedagogical strategies, ensuring alignment with curriculum objectives while addressing diverse learning needs. Future research should investigate the long-term effects of gamification on motivation and academic performance, as well as explore the optimal design features of SEGs that can maximize educational outcomes for students with learning difficulties. By continuing to develop and implement effective gamified interventions, educators can significantly enhance the learning experiences of students with DD, ultimately leading to improved academic success and greater confidence in their mathematical abilities.

## LIMITATIONS

This study has several limitations. The sample size, while adequate for statistical analysis, may not fully represent the diverse population of sixth-grade students with DD. A larger and more diverse sample could enhance the generalizability of the findings.

Additionally, the study's duration was limited to a single instructional period, which may not capture the long-term effects of digital serious educational games (SEGs) on mathematical performance and motivation. Future research should consider longer-term studies to assess sustained engagement.

The motivation measure relied on self-reported scores, which may introduce bias. Incorporating objective measures could provide more accurate insights. Furthermore, the specific design and integration of the digital game into the curriculum were not thoroughly evaluated, which may impact the outcomes.

Parameters such as reading/spelling disorders, as well as math anxiety, were not controlled for in this study, which could influence the results and their interpretation. Addressing these limitations in future studies can enhance the understanding of gamification in education.

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**DECLARATION OF INTEREST STATEMENT**

The author reported no potential conflict of interest.

**ETHICAL STATEMENT**

This study was conducted in accordance with ethical guidelines and received approval from the Internal Ethics and Deontology Committee of the Department of Special Education at the University. The approval was granted following the committee's session on April 23, 2024 (protocol #199).

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**REFERENCES**

Altundağ, C. K. & Uzunaslan, S. (2023). Design of Educational and Digital Games for Students with Dyscalculia to Transfer Mathematics to Their Daily Lives. In S. Rakich (Ed.), *Cases on Current Issues, Challenges, and Opportunities in School Counseling (pp. 200-221). IGI Global.* https://doi.org/10.4018/978-1-6684-7556-0.ch011

Anaekwe, C. M. (2007). *Basic research methods and statistics in education and social sciences*. Sofie Publicity and Printry Ltd.

Avila-Pesantez, D. F., Vaca-Cardenas, L. A., Delgadillo Avila, R., Padilla Padilla, N., & Rivera, L. A. (2019). Design of an augmented reality serious game for children with dyscalculia: A case study. In M. Botto-Tobar, G. Pizarro, M. Zúñiga-Prieto, M. D'Armas, & M. Zúñiga Sánchez (Eds.), *Technology trends. CITT 2018. Communications in computer and information science* (Vol. 895, pp. 131–141). Springer. https://doi.org/10.1007/978-3-030-05532-5_12

Becker, K. (2010). Distinctions Between Games and Learning: A Review of Current Literature on Games in Education. In R. Van Eck (Ed.), *Gaming and Cognition: Theories and Practice from the Learning Sciences (pp. 22-54).* IGI Global Scientific Publishing. https://doi.org/10.4018/978-1-61520-717-6.ch002

Bozkurt, A., & Durak, G. (2018). A systematic review of gamification research: In pursuit of homo ludens. *International Journal of Game-Based Learning, 8*(3), 15–33. https://doi.org/10.4018/IJGBL.2018070102

Butterworth, B., & Kovas, Y. (2013). Understanding neurocognitive developmental disorders can improve education for all. *Science*, *340*(6130), 300–305. https://doi.org/10.1126/science.1231022

Castaldi, E., Piazza, M., & Iuculano, T. (2020). Learning disabilities: Developmental dyscalculia. In D. Mareschal & B. Butterworth (Eds.), *Handbook of Mathematical Cognition* (pp. 205-227). Oxford University Press.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Routledge.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage.

Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry*, *11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Dehghanzadeh, H., Farrokhnia, M., Dehghanzadeh, H., Taghipour, K., & Noroozi, O. (2023). Using gamification to support learning in K-12 education: A systematic literature review. *British Journal of Educational Technology, 55*(1), 34–70. https://doi.org/10.1111/bjet.13335

Deterding, S., Sicart, M., Nacke, L., O'hara, K., & Dixon, D. (2011). Gamification. using game-design elements in non-gaming contexts. In CHI'11 extended abstracts on human factors in computing systems (pp. 2425-2428). https://doi.org/10.1145/1979742.1979575

Dhingra, K., Aggarwal, R., Garg, A., Pujari, J., & Yadav, D. (2024). Mathlete: an adaptive assistive technology tool for children with dyscalculia. *Disability and rehabilitation. Assistive technology*, *19*(1), 9–15. https://doi.org/10.1080/17483107.2022.2134473

Dowker, A. (2024). Developmental dyscalculia in relation to individual differences in mathematical abilities. *Children, 11*(6), 623. https://doi.org/10.3390/children11060623

Gentile, D. (2009). Pathological Video-Game Use among Youth Ages 8 to 18: A National Study. *Psychological Science*, *20*(5), 594-602. https://doi.org/10.1111/j.1467-9280.2009.02340.x

Ghanbaripour, A. N., Talebian, N., Miller, D., Tumpa, R. J., Zhang, W., Golmoradi, M., & Skitmore, M. (2024). A systematic review of the impact of emerging technologies on student learning, engagement, and employability in built environment education. *Buildings, 14*(9), Article 2769. https://doi.org/10.3390/buildings14092769

Holman, K. (2023). Interventions for Students With Developmental Dyscalculia: A Systematic Literature Review. Insights into Learning Disabilities, 20(2), 135151. https://eric.ed.gov/?id=EJ1401956

Hwang, G.-J., Hsu, T.-C., Lai, C.-L., & Hsueh, C.-J. (2017). Interaction of problem-based gaming and learning anxiety in language students' English listening performance and progressive behavioral patterns. *Computers & Education, 106,* 26–42. https://doi.org/10.1016/j.compedu.2016.11.010

Ioannou, A. (2019). A model of gameful design for learning using interactive tabletops: Enactment and evaluation in the socio-emotional education classroom. *Educational Technology Research and Development, 67*(2), 277–302. https://doi.org/10.1007/s11423-018-9610-1

Jadán-Guerrero, J., Avilés-Castillo, F., Buele, J., & Palacios-Navarro, G. (2023). Gamification in inclusive education for children with disabilities: Global trends and approaches - A bibliometric review. In O. Gervasi, B. Murgante, A. M. A. C. Rocha, C. Garau, F. Scorza, Y. Karaca, & C. M. Torre (Eds.), *Computational science and its applications – ICCSA 2023 workshops* (Vol. 14104, pp. 461–477). Springer. https://doi.org/10.1007/978-3-031-37105-9_31

Käser, T., Baschera, G. M., Kohn, J., Kucian, K., Richtmann, V., Grond, U., Gross, M., & von Aster, M. (2013). Design and evaluation of the computer-based training program Calcularis for enhancing numerical cognition. *Frontiers in psychology*, *4*, 489. https://doi.org/10.3389/fpsyg.2013.00489

Kohn, J., Rauscher, L., Kucian, K., Käser, T., Wyschkon, A., Esser, G., & von Aster, M. (2020). Efficacy of a computer-based learning program in children with developmental dyscalculia: What influences individual responsiveness? *Frontiers in Psychology, 11*, 1115. https://doi.org/10.3389/fpsyg.2020.01115

Koivisto, J., & Hamari, J. (2019). The rise of motivational information systems: A review of gamification research. *International Journal of Information Management, 45*, 191–210. https://doi.org/10.1016/j.ijinfomgt.2018.10.013

Kucian, K., & von Aster, M. (2015). Developmental dyscalculia. *European Journal of Pediatrics, 174,* 1–13. https://doi.org/10.1007/s00431-014-2455-7

Lei, H., Chiu, M. M., Wang, D., Wang, C., & Xie, T. (2022). Effects of Game-Based Learning on Students' Achievement in Science: A Meta-Analysis. *Journal of Educational Computing Research*, *60*(6), 1373-1398. https://doi.org/10.1177/07356331211064543

Lemmens, J. S., Valkenburg, P. M., & Peter, J. (2009). Development and Validation of a Game Addiction Scale for Adolescents. *Media Psychology*, *12*(1), 77–95. https://doi.org/10.1080/15213260802669458

Li, M., Ma, S., & Shi, Y. (2023). Examining the effectiveness of gamification as a tool promoting teaching and learning in educational settings: A meta-analysis. *Frontiers in Psychology, 14.* https://doi.org/10.3389/fpsyg.2023.1253549

Mekler, E. D., Brühlmann, F., Tuch, A. N., & Opwis, K. (2017). Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in Human Behavior, 71*, 525–534. https://doi.org/10.1016/j.chb.2015.08.048

Papastergiou, M. (2009). Digital Game-Based Learning in High School Computer Science Education: Impact on Educational Effectiveness and Student Motivation. Computers & Education, 52, 1-12. http://dx.doi.org/10.1016/j.compedu.2008.06.004

Partovi, T., & Razavi, M. R. (2019). The effect of game-based learning on academic achievement motivation of elementary school students. *Learning and Motivation*, *68*, Article 101592. https://doi.org/10.1016/j.lmot.2019.101592

Polydoros, G., & Antoniou, A. S. (2025). Empowering Students with Learning Disabilities: Examining Serious Digital Games' Potential for Performance and Motivation in Math Education. *Behavioral sciences*, *15*(3), 282. https://doi.org/10.3390/bs15030282

Plass, J. L., Homer, B. D., Mayer, R. E., & Kinzer, C. K. (2020). Theoretical foundations of game-based and playful learning. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of game-based learning (pp. 3–24). The MIT Press.*

Putz, L. M., Hofbauer, F., & Treiblmaier, H. (2020). Can gamification help to improve education? Findings from a longitudinal study. *Computers in Human Behavior, 110*, 106392. https://doi.org/10.1016/j.chb.2020.106392

Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior, 69*, 371–380. https://doi.org/10.1016/j.chb.2016.12.033

Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review, 32*(1), 77–112. https://doi.org/10.1007/s10648-019-09498-w

Sanchez, D. R., Langer, M., & Kaur, R. (2020). Gamification in the classroom: Examining the impact of gamified quizzes on student learning. *Computers & Education, 144,* 103666. https://doi.org/10.1016/j.compedu.2019.103666

Schrader, C. (2023). Serious games and game-based learning. In O. Zawacki-Richter, & I. Jung, (Eds.), *Handbook of open, distance and digital education* (pp. 1255–1268). Springer. https://doi.org/10.1007/978-981-19-2080-6_74

Siadaty, M., Gašević, D., & Hatala, M. (2016). Measuring the impact of technological scaffolding interventions on micro-level processes of self-regulated workplace learning. *Computers in Human Behavior, 59,* 469–482. https://doi.org/10.1016/j.chb.2016.02.025

Vankúš, P. (2021). Influence of game-based learning in mathematics education on students' affective domain: A systematic review. *Mathematics, 9*(9), 986. https://doi.org/10.3390/math9090986

Vasalou, A., Joinson, A., Bänziger, T., Goldie, P., & Pitt, J. (2008). Avatars in social media: Balancing accuracy, playfulness and embodied messages. *International Journal of Human-Computer Studies, 66*(11), 1035-1048. https://doi.org/10.1016/j.ijhcs.2008.08.002

Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education, 14*(1), 22. https://doi.org/10.1186/s41239-017-0062-1

Yu, Z., Gao, M., & Wang, L. (2021). The Effect of Educational Games on Learning Outcomes, Student Motivation, Engagement and Satisfaction. *Journal of Educational Computing Research*, *59*(3), 522-546. https://doi.org/10.1177/0735633120969214

Zainuddin, Z. (2018). Students' learning performance and perceived motivation in gamified flipped-class instruction. *Computers & Education, 126*, 75–88. https://doi.org/10.1016/j.compedu.2018.07.003

Zainuddin, Z., Chu, S. K. W., Shujahat, M., & Perera, C. J. (2020). The impact of gamification on learning and instruction: A systematic review of empirical evidence. *Educational Research Review, 30,* 100326. https://doi.org/10.1016/j.edurev.2020.100326

Zhang, J., Rodrigo, M. M., Matsuda, N., Cristea, A. I., & Dimitrova, V. (2022). Investigating student interest and engagement in game-based learning environments. In M. M. Rodrigo, N. Matsuda, A. I. Cristea, & V. Dimitrova (Eds.), *Artificial intelligence in education: AIED 2022* (Vol. 13355, pp. 711–716). Springer. https://doi.org/10.1007/978-3-031-11644-5_72