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Sociocultural Game-Based Interactive Digital Simulations: A Pathway to Improving Primary School Students' Word Problem-Solving Skills

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ABSTRACT

In this study, we explore the implementation of a sociocultural game-based interactive digital simulation titled The Adventure of Adit in the Fruit Store game in mathematics learning. The microgenetic method was applied to examine the dynamic changes in students' word problem-solving (WPS) abilities. A total of 140 first-grade students, comprising 57 boys and 83 girls with an average age of 6 to 7 years, participated in six mathematics sessions. We collaborated with the classroom teacher to design a mathematics lesson using the game we designed to teach number addition (1-10). A pre-test and six assessments were administered to students after they engaged with the mathematics learning design. Descriptive statistics were used to analyse the dynamic changes in students' WPS abilities over time, and the Wilcoxon Signed Ranks Test was conducted to compare students' WPS abilities before and after participation in mathematics learning through the game. Our findings demonstrate significant dynamic improvements in students' WPS abilities following participation in the designed mathematics lesson. Moreover, statistical analysis revealed a significant improvement in students' post-test scores compared to pre-test scores, $Z = -10.380$, $p < .001$, indicating that the game-based learning intervention had a substantial effect on enhancing students' word problem-solving skills

Keywords: Game-based learning, quasi-experiment, sociocultural, word problem solving

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INTRODUCTION

Mathematics education plays a crucial role in preparing students to understand, interpret,

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and respond to the quantitative demands of everyday life. Beyond developing procedural fluency and computational skills, mathematics learning is expected to foster students' ability to reason, make decisions, and solve problems in meaningful real-world contexts (NCTM, 2014). Consequently, problem solving has long been recognised as a central goal of mathematics education and an essential indicator of mathematical proficiency (Olsson & Granberg, 2024). Students who can successfully apply mathematical knowledge to authentic situations are better equipped to use mathematics as a tool for understanding and navigating the world around them. One of the most important ways in which this competency is demonstrated is through solving mathematical word problems, which require students to interpret contextual information, translate it into mathematical representations, and determine appropriate solutions (Bjork & Bowyer-Crane, 2013; Verschaffel et al., 2020). Mathematical word problems are exercises that present relevant information in written text rather than using mathematical symbols (Vicente et al., 2020). Therefore, developing word problem-solving skills is a key component of effective mathematics teaching and learning.

Word-problem proficiency is essential for enabling students to connect mathematical concepts with real-life situations and to achieve success in broader academic contexts (Reinhold et al., 2020; Vilenius-Tuohimaa et al., 2008). Through word problems, students develop higher-order cognitive skills, including reasoning, organisation, and problem-solving abilities, while also applying mathematical knowledge in meaningful contexts (Browder et al., 2018). Furthermore, word problems provide opportunities for students to practice basic mathematical operations in varied situations and prepare them to use mathematical skills effectively in everyday life (Pongsakdi et al., 2020). However, word problems are widely recognised as one of the most challenging aspects of mathematics learning because they present mathematical information in linguistic and contextual forms rather than as straightforward numerical operations (Sepeng & Madzorera, 2014; Verschaffel et al., 2020). Successfully solving word problems requires students to coordinate multiple cognitive processes, including comprehending the language and semantic structure of the problem, accurately representing its mathematical components, selecting and implementing appropriate solution strategies, and retrieving relevant knowledge from memory (Alghamdi et al., 2020; Browder et al., 2018). These complex demands often make word-problem solving particularly difficult for young learners.

Research has demonstrated that integrating digital simulations into mathematics learning environments can provide students with interactive and authentic contexts for applying mathematical concepts (Chen et al., 2023; Sun-Lin & Chiou, 2019). Through dynamic exploration and experimentation, digital simulations enable learners to construct a deeper understanding of mathematical principles and their real-world applications (Cai et al.,

2022). Furthermore, the adaptive capabilities embedded in many digital learning platforms can personalise instruction by responding to individual students' learning needs and providing targeted support for specific areas of difficulty (Chang & Yang, 2023). Beyond supporting conceptual understanding and individualised learning, digital simulations can be enhanced through gamification features, such as rewards, feedback systems, and progress tracking, which have been shown to increase student engagement and encourage persistence in solving mathematical problems (Chen et al., 2023).

Although digital simulations have demonstrated considerable potential for supporting mathematics learning (Dan, 2024; Geiger et al., 2015) their role in fostering students' word problem-solving abilities remains underexplored, particularly in the context of early primary education. Prior studies have predominantly evaluated intervention effectiveness through pre- and post-intervention measures, offering limited insight into how students' word problem-solving abilities develop and change throughout the learning process (Jensen & Skott, 2022; Vanbecelaere et al., 2020). Moreover, existing research on game-based digital learning has rarely integrated sociocultural elements that situate mathematical problems within learners' everyday experiences and cultural environments. Such integration is important, as meaningful contextualisation may facilitate students' interpretation of problem situations and the application of mathematical reasoning (Chen et al., 2023). Therefore, there is a need for research that examines the potential of sociocultural game-based digital simulations to enhance students' word problem-solving abilities.

This study aims to analyse the impact of implementing sociocultural game-based interactive digital simulations on enhancing students' abilities in solving mathematical word problems. Building on previous research showing the benefits of digital simulations in creating interactive and authentic learning experiences (Zheng et al., 2024), this study investigates how game-based elements such as dynamic exploration, adaptive support, and gamification (Cai et al., 2022; Chang & Yang, 2023) can foster deeper engagement and improve problem-solving skills. Specifically, the research questions addressed in this study are:

How does the dynamic change of students' WPS abilities during their participation in learning with The Adventure of Adit in the Fruit Store game?

Does the implementation of The Adventure of Adit in the Fruit Store game significantly enhance students' word problem-solving abilities?

LITERATURE REVIEW

Sociocultural View of Learning

In mathematics education, the sociocultural view of learning emphasises that mathematical understanding develops through social interaction and engagement with culturally relevant practices. Mathematics is not just a collection of abstract concepts but is embedded in real-world practices, language, and shared tools that shape how students perceive

and solve mathematical problems (Goos, 2013). Within this framework, students learn mathematics more effectively when it is connected to their social and cultural experiences, allowing them to engage with the subject in ways that are meaningful to them (Steele, 2001). For example, incorporating culturally relevant contexts into word problems or using familiar objects and practices can help students understand mathematical concepts more deeply, as they can relate these ideas to their everyday lives and community practices (Reinhold et al., 2020).

From a sociocultural perspective, learning is fundamentally a process of participation in socially and culturally situated practices rather than the mere acquisition of knowledge by individuals. Mathematical understanding emerges through interactions with peers, teachers, and cultural tools that mediate thinking and problem-solving processes (Lee et al., 2020). Knowledge is therefore co-constructed through dialogue, collaboration, and shared activity within a learning community (Damsa & Ludvingsen, 2016). This perspective highlights the importance of providing students with authentic learning experiences in which mathematical ideas are explored, negotiated, and applied in meaningful contexts. As students participate in such activities, they gradually appropriate the ways of reasoning, communicating, and problem-solving that characterise mathematical practice, enabling them to develop deeper conceptual understanding and more flexible approaches to solving problems.

Teachers play a critical role in facilitating this type of learning by creating collaborative environments where students can explore mathematical ideas together and learn from each other's perspectives (Shabani, 2016). This can be achieved through group activities, peer discussions, and project-based learning, where students work within their "zone of proximal development" to develop mathematical skills with the guidance of more knowledgeable peers or a teacher (Lambright, 2023). In such settings, students engage in "mathematising" the process of interpreting and solving problems in ways that make sense within their cultural contexts (Dreher et al., 2024). By fostering a sociocultural approach to mathematics education, teachers can help students see math not as isolated from their lives but as a tool for understanding and addressing real-world problems (Prahmana, 2022). This approach not only enhances mathematical problem-solving skills but also builds students' confidence and motivation by showing them the relevance of mathematics in their everyday lives.

Game-based Learning

Game-based learning in mathematics education leverages the motivational and interactive elements of games to create a more engaging and effective learning environment for students (Chen et al., 2023). In game-based learning, students can explore mathematical concepts through simulations, challenges, and problem-solving tasks within a structured game environment that

often includes rewards, feedback, and levels of progression (Hussein et al., 2022). This approach transforms mathematics from a traditional, often abstract subject into an interactive experience where students can experiment, make mistakes, and learn from them in a safe space (Guo et al., 2024). Through immediate feedback and incentives, students are encouraged to persist in solving problems, fostering both perseverance and a growth mindset essential in math learning.

Research has shown that game-based learning in mathematics can significantly improve students' engagement, understanding, and retention of mathematical concepts (Brezovszky et al., 2019; Zheng et al., 2024). When applied thoughtfully, games can help develop critical thinking and problem-solving skills by presenting real-world scenarios that require students to apply math in practical ways (Chen et al., 2024). For instance, games focussed on budgeting, measuring, or spatial reasoning can demonstrate the relevance of mathematics to daily life, making the subject more accessible and meaningful. Additionally, adaptive game-based platforms can tailor content to individual learning needs, offering personalised challenges that help students master foundational skills at their own pace (Sun et al., 2021). Through these interactive and personalised experiences, game-based learning can not only make mathematics more enjoyable but also empower students with confidence and competence in the subject (Vanbecelaere et al., 2020).

Mathematics Digital Simulation

Digital simulation in mathematics learning provides students with a dynamic, interactive platform to explore mathematical concepts and practice problem-solving in realistic contexts (Geiger et al., 2015). Unlike traditional approaches, digital simulations immerse students in environments where they can visualise and manipulate mathematical elements directly, allowing for a deeper understanding of complex ideas through hands-on experimentation (Chen et al., 2023; Geiger et al., 2015). These simulations often include interactive features, such as adjustable variables, visual feedback, and real-time data, which enable students to see the immediate effects of their actions and test hypotheses. For instance, in simulations that involve geometry or algebra, students can manipulate shapes or equations to observe changes, helping them build an intuitive understanding of mathematical relationships.

Research indicates that digital simulations not only improve students' engagement with mathematics but also enhance conceptual understanding by presenting abstract mathematical concepts in a more accessible and relatable format (Viberg et al., 2023). For example, a digital simulation focussed on probability might allow students to simulate countless random events, enabling them to visualise probability distributions and understand statistical concepts more concretely. Digital platforms can also incorporate adaptive features to adjust the difficulty level based on each student's progress, providing targeted

support for those who need additional help and advancing students who are ready for more complex challenges (Loong & Herbert, 2018; Sümmermann et al., 2021). By making abstract concepts tangible and offering individualised learning pathways, digital simulations support a deeper, more personalised approach to mathematics learning that can foster both skill acquisition and sustained interest in the subject.

Word Problem Solving

Word problem-solving in mathematics education is crucial, particularly for young students, as it bridges the gap between abstract math concepts and real-life applications (Vicente et al., 2020). For elementary-age students, solving word problems builds foundational skills in mathematical reasoning, critical thinking, and comprehension (Boonen et al., 2016). At this age, children are developing their ability to interpret and analyse information, so using word problems relevant to their everyday experiences—like sharing snacks, counting toys, or understanding time-makes math more relatable and meaningful (NCTM, 2000). By connecting mathematical operations to situations familiar to students, educators can enhance their engagement and motivation to solve problems, building confidence in their math abilities early on.

Young learners often struggle with the language and contextual nuances of word problems, which can make it challenging to identify the relevant mathematical operations needed (Verschaffel et al., 2020). To support students in overcoming these challenges, teachers can introduce structured problem-solving strategies, such as visualisation, drawing diagrams, or breaking down problems into manageable steps (Naude et al., 2022). Additionally, incorporating collaborative activities where students discuss and approach word problems together can provide peer support and exposure to diverse problem-solving methods. Interactive tools, like digital simulations or game-based learning platforms, can further reinforce these skills by allowing students to experiment with word problems in a guided and adaptive environment that adjusts to their pace and learning needs (Dewolf et al., 2014; Sun-Lin & Chiou, 2019). By providing appropriate instructional support and engaging learning experiences, educators can help young learners develop stronger word problem-solving skills and build a solid foundation for future mathematical learning.

METHODS

Design

This study employs a microgenetic design (Siegler & Crowley, 1991), which enables researchers to analyse the dynamic changes in students' cognitive abilities in word problem-solving (WPS). The microgenetic method involves frequent, detailed observations of learning processes over a short period, allowing us to capture the progression and transformation of students' cognitive skills as they engage in problem-solving tasks. In this study, we specifically analysed changes in students' WPS abilities after each mathematics learning session using The

Adventure of Adit in the Fruit Store, a game designed to support students in learning mathematics through gameplay and solving WPS related to addition with numbers 1-10. This approach provides insights into the nuanced changes in students' understanding and strategy use as they progressed through each session, revealing how game-based learning can foster cognitive development in mathematics.

Intervention Design

Pre-treatment

The students were given a special session to introduce them to the features of the game used in the learning process. This session was essential to help students understand how the game functions so they could participate in the activities more effectively. The students were taught how to use a mouse, as most of the first-grade students had never learned in a computer lab before. In this session, students were also shown examples of how to perform specific tasks within the game, such as how to drag and drop objects by moving them from one part of the screen to another, how to enter numbers into the answer box, and how to check their answers after completing a task. These demonstrations were crucial in ensuring the students could interact with the game effectively during the learning process.

After ensuring that all students were able to operate the game, a pre-test was conducted to assess their word problem-solving abilities. The students completed a set of 10 questions from the word problem-solving test (WPST), designed to measure their proficiency in performing addition operations within the range of 1 to 10. This pre-test served as a baseline to evaluate the students' initial capabilities before the treatment began.

Treatment Session

The treatment sessions were conducted the following day after the students completed the trial and pre-test. The students played the game for six consecutive days, with each session lasting 20 minutes. The six-session intervention was intentionally designed to provide sufficient opportunities for repeated practice and reinforcement of mathematical problem-solving strategies. This duration was considered appropriate for first-grade students, allowing them to become familiar with the game environment and learning tasks while maintaining their engagement and motivation throughout the intervention period. In addition, the repeated sessions supported students' gradual progression through Bruner's enactive, iconic, and symbolic modes of representation embedded within the game design, thereby facilitating deeper conceptual understanding and the development of word problem-solving skills.

This structured time frame allowed the students to engage with the game consistently while ensuring enough practice to enhance their word problem-solving skills. Figure 1 presents several components of *The Adventure of Adit in the Fruit Store* game, including the main menu interface, examples of students' interactions during

Figure 1. Example of the game-based mathematics simulation showing the main menu and instructional content

gameplay, and sample evaluation tasks used to assess students' understanding of addition word problems. These features illustrate how the game integrates learning activities, problem-solving tasks, and assessment within a single interactive environment.

In this activity, the students had to drag objects from one area of the screen to another, which helped them solve problems related to addition. This interactive feature was designed to make the learning experience more engaging and to improve their understanding of mathematical concepts. As illustrated in Figure 2, the game was structured through several interconnected components, including the Info Game Board, How to Play section, and a series of game activities accessible through the Game Menu. The learning activities consisted of Counting Apples in the Fruit Shop, Arranging Oranges on the Shelf, Counting Bananas in the Shop, Managing Fruit Inventory, and an Evaluation section. Each activity was designed to provide opportunities for students to practice addition through contextualised problem-solving tasks. Supporting features such as drag-and-drop interaction, immediate feedback, a scoring and reward system, animations, sounds, and offline accessibility were integrated to enhance engagement and learning effectiveness. Furthermore, the overall game design incorporated sociocultural elements by situating mathematical problems within a familiar fruit shop environment, enabling students to connect abstract addition concepts with meaningful real-life experiences.

Post-treatment

After completing all sessions over the six days using the game, the students were given a post-test. This post-test consisted of 10 questions aimed at measuring the students'

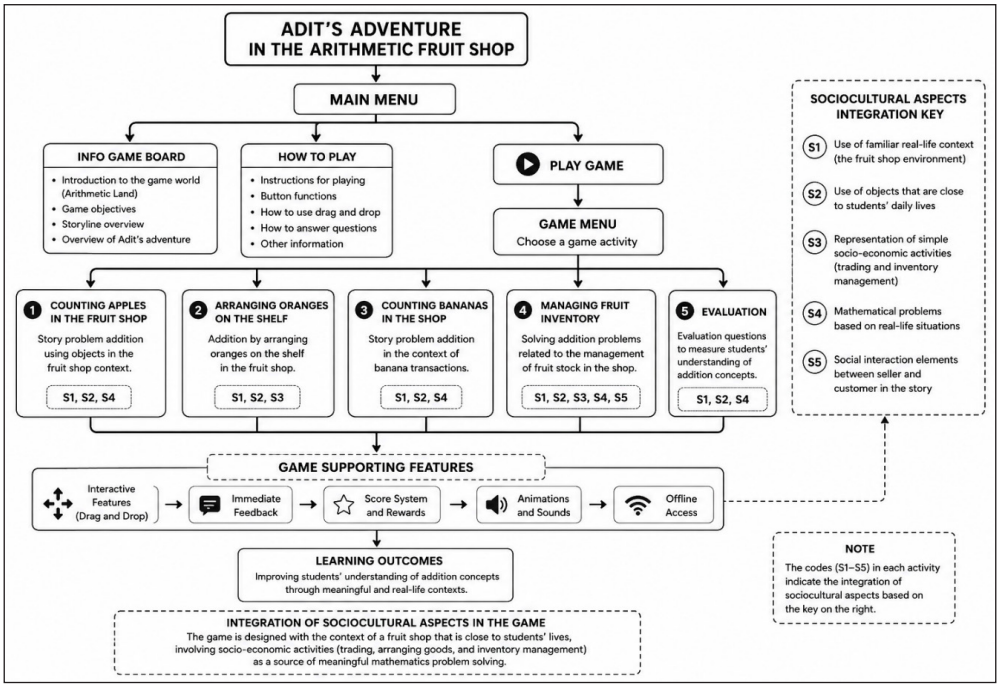

Figure 2. Structure and sociocultural integration of the game-based mathematics interactive simulation "Adit's Adventure in the Arithmetic Fruit Shop"

WPS skills. The results of the post-test were used to evaluate any improvements in their abilities following the treatment.

Instrumentation and Test Procedures

To assess the students' word problem-solving (WPS) abilities, the researchers developed a WPST instrument tailored to evaluate skills in addition within the range of 1-10. The test questions were designed with careful attention to using language that is clear and understandable for first-grade students and ensuring that the content aligns with the context of the game. This strategy aimed to make the assessment both relevant and accessible. Before administering the test, feedback was obtained from two experienced first-grade teachers, each with over 5 years of teaching experience. They reviewed the questions for content and language appropriateness. Based on their input, revisions were made to enhance the clarity and effectiveness of the questions.

WPS Test Validity and Reliability

To further ensure the appropriateness of the instrument, a content validity review was conducted by two experts in primary mathematics education. The experts evaluated the extent to which each item aligned with the targeted indicators of word problem-solving abilities and assessed the readability of the questions for first-grade students. Attention was given to the correspondence between the mathematical skills intended to be measured and the

problem situations presented in the items, as well as to the clarity and comprehensibility of the language used. Based on the experts' recommendations, minor revisions were made to improve item wording and strengthen the alignment between the assessment tasks and the intended learning indicators. The final version of the WPST was deemed suitable for assessing students' word problem-solving abilities within the scope of addition from 1 to 10.

Following the content validation process, the reliability of the Word Problem-Solving Test (WPST) was examined using the Kuder-Richardson Formula 20 (KR-20), which is equivalent to Cronbach's alpha for dichotomously scored items (1 = correct, 0 = incorrect). A pilot test involving 17 first-grade students was conducted before the main study. The analysis yielded a reliability coefficient of 0.769, indicating acceptable to good internal consistency among the test items. This result suggests that the instrument was sufficiently reliable for measuring students' word problem-solving abilities in addition tasks within the range of 1-10. Consequently, the final version of the WPST was considered appropriate for use in the main study.

Participants

The participants of this study were 140 first-grade students in Malang, Indonesia. Approval by the school headmaster and classroom teacher was obtained before they participated in this study. The demographic of the students who participated in this study is presented in Table 1.

As presented in Table 1, the students who participated in this study were first-grade students with 6 to 7 years old on average. There were 57 male and 83 female students (Table 2).

Table 1
Test period procedure

No.	Test	Time	Number of Problems
1.	Pre-test	Before the treatment	10 WPS
2.	Test 1	After Session 1	10 WPS
3.	Test 2	After Session 2	10 WPS
4.	Test 3	After Session 3	10 WPS
5.	Test 4	After Session 4	10 WPS
6.	Test 5	After Session 5	10 WPS
7.	Post-Test	After Session 6	10 WPS

Table 2
Demographics of the participants

Gender	Number of Students	Average Age
Male	57	6.7
Female	83	6.8

Data Analysis

To evaluate the effectiveness of the game in enhancing students' word problem-solving (WPS) skills, a statistical test was conducted by comparing the pre-test and post-test results. The statistical test was conducted through the Wilcoxon signed-rank test on the data collected from 140 students who participated in the study. The purpose of the t-test was to determine whether there was a statistically significant difference in the students' WPS abilities before and after the intervention.

RESULTS

Dynamic Change of Students' Word Problem-solving Abilities

Descriptive statistics were used to analyse the dynamic changes in students' word problem-solving (WPS) performance across seven tests during their participation in mathematics learning with the Adventure of Adit in the Fruit Store game. The results are presented in Figure 3, showing the dynamic change of students' WPS abilities throughout the learning sessions.

Based on Figure 3, there is a visible dynamic change in students' word problem-solving (WPS) performance, as indicated by the mean scores across multiple assessments. The mean scores were as follows: Pre-Test (M = 51.14), Test 1 (M = 59.93), Test 2 (M = 65.79), Test 3 (M = 70.57), Test 4 (M = 76.14), Test 5 (M = 80.57), and Post-Test (M = 81.43). This progression reflects a continuous improvement in students' WPS abilities throughout the intervention with the Adventure of Adit in the Fruit Store game. The improvement can be attributed to the game's interactive design, which required students to actively solve addition-related word problems through drag-and-drop activities and immediate feedback. Through repeated interactions

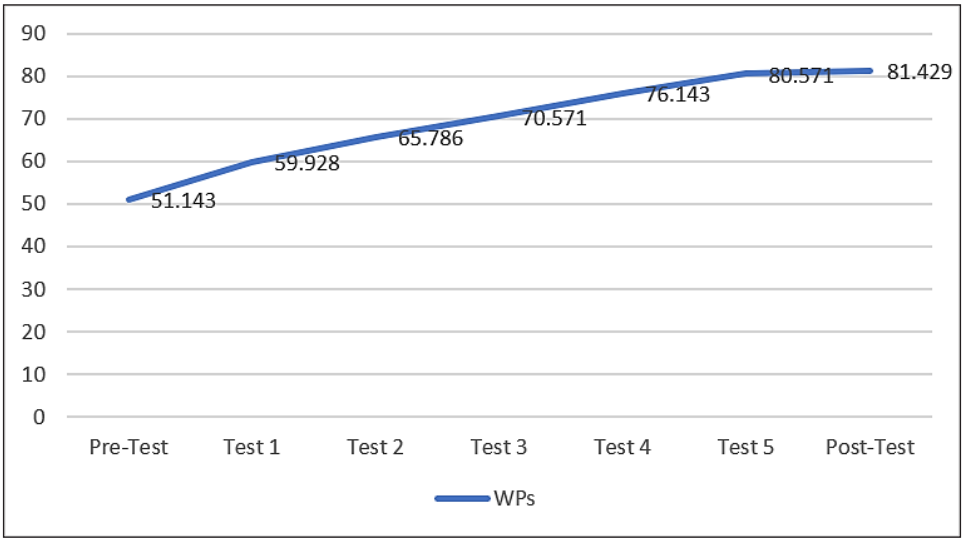

Figure 3. Students' dynamic changes in WPS abilities

with mathematical tasks, students continuously practised identifying relevant information, representing quantities, and determining appropriate solutions. The game environment also enabled students to connect concrete actions with visual and symbolic mathematical representations, thereby strengthening their conceptual understanding of addition. In addition, the engaging nature of the game promoted sustained participation and repeated practice, which are essential for the development of mathematical problem-solving skills. The integration of Bruner's enactive, iconic, and symbolic representations further supported students' progression from concrete manipulation to abstract reasoning, contributing to the consistent gains observed in their WPS performance.

Students' Improvement in Word Problem-solving Abilities

The first step in measuring the effectiveness of using The Adventure of Adit in the Fruit Store game on students' word problem-solving (WPS) abilities involves conducting a normality test of the data. This preliminary test ensures that the data distribution meets the assumptions of normality, which is crucial for determining the appropriate statistical methods for analysing the impact of the game on students' WPS abilities. A normality test was conducted to ensure that the obtained data followed a normal distribution. The results of this test are displayed in Table 3.

Based on the normality test analysis of pre-test and post-test scores for students' WPS abilities, the Kolmogorov-Smirnov test indicates that the data are not normally distributed. For the pre-test scores, the Kolmogorov-Smirnov statistic was $D(140) = 0.181$, $p < 0.001$, and for the post-test scores, $D(140) = 0.178$, $p < 0.001$, where a p-value less than 0.05 suggests a significant deviation from normality. Therefore, non-parametric statistical methods should be applied in further analysis to accurately evaluate the impact of The Adventure of Adit in the Fruit Store game on students' WPS abilities.

The results of the Wilcoxon Signed Ranks Test (Table 4) reveal a statistically significant increase in students' word problem-solving (WPS) abilities after using The Adventure of Adit in the Fruit Store game.

Table 3
Normality test of pre- and post-test WPS score

	N	Kolmogorov-Smirnov Statistic (D)	p-value
Pre-Test	140	0.181	<0.001
Post-Test	140	0.178	<0.001

Table 4
Wilcoxon Signed Ranks test results for pre-test and post-test scores of students' word problem-solving abilities

	N	Z	p-value
Pre-test vs. post-test	140	-10.380	< 0.001

With a sample size of N = 140, the test yielded a Z value of -10.380, with a p-value of < 0.001, indicating a significant effect ($p < 0.05$). This result suggests that the game-based intervention had a positive impact on improving students' WPS abilities, supporting the effectiveness of using interactive simulations in mathematics learning for young students.

DISCUSSION

The results of this study indicate a significant improvement in students' word problem-solving (WPS) abilities following the intervention with The Adventure of Adit in the Fruit Store game. The Kolmogorov-Smirnov test showed that both pre-test and post-test scores were not normally distributed ($p < 0.001$), necessitating the use of the Wilcoxon Signed Ranks Test as a non-parametric measure to assess the changes. Results from the Wilcoxon test confirmed a statistically significant increase in post-test scores compared to pre-test scores ($Z = -10.380$, $p < 0.001$), highlighting the positive effect of game-based learning on students' WPS abilities.

The improvement in scores suggests that The Adventure of Adit in the Fruit Store game provided an engaging and dynamic learning environment, helping students practice problem-solving in meaningful, real-world contexts. Game-based learning has been shown to enhance motivation and engagement by creating an interactive platform where students actively participate in their own learning (Brezovszky et al., 2019; Chen et al., 2023). Such interactive environments may improve focus and foster persistence in tackling word problems, which are often challenging for young learners.

Beyond increasing engagement, the game may have supported students in connecting mathematical symbols and operations with meaningful situations. Word problems require students not only to perform calculations but also to interpret linguistic information, identify relevant quantities, and construct mathematical representations of real-world situations (Csíkos & Szitányi, 2020). These processes are often difficult for first-grade students because they are still developing both their mathematical understanding and reading comprehension skills (Verschaffel et al., 2020). By embedding addition tasks within familiar activities such as buying and counting fruits, the game reduced the abstract nature of mathematics and enabled students to visualise the relationships among quantities more effectively. This finding supports previous studies suggesting that contextualised digital environments can facilitate students' understanding of mathematical concepts and improve their ability to translate everyday situations into mathematical expressions (Cai et al., 2022; Guo et al., 2024).

Furthermore, the structure of the game aligns with cognitive development theories, such as Vygotsky's social constructivism, which emphasises learning through interaction and contextualised tasks (Vygotsky, 1978). By offering a simulation of real-life scenarios, the game allows

students to engage with mathematical concepts in a familiar setting, facilitating better understanding and retention (Sun et al., 2021). Studies have shown that contextual learning approaches, particularly those involving real-world simulations, are effective in developing mathematical reasoning and problem-solving skills (Cai et al., 2022; Guo et al., 2024; Vanbecelaere et al., 2020).

An important feature distinguishing this study from many previous investigations is the integration of sociocultural elements into the digital learning environment. The game context was designed to reflect situations that are familiar to young learners, allowing them to interact with mathematical ideas through culturally meaningful experiences. From a sociocultural perspective, learning occurs most effectively when new knowledge is connected to learners' prior experiences and social environments (Goos, 2013; Shabani, 2016). The fruit store scenario provided opportunities for students to engage with mathematical tasks that resembled everyday activities, thereby supporting sense-making and reducing cognitive barriers associated with abstract mathematical problems. This finding is consistent with research emphasising the importance of culturally relevant and contextually grounded learning experiences in promoting mathematical understanding and problem-solving performance (Dreher et al., 2024).

The findings also provide insight into how digital simulations can support the development of problem-solving processes rather than merely improving outcomes. Through repeated interactions with game tasks, students received immediate feedback, opportunities for correction, and multiple chances to explore alternative solutions (Dan, 2024; Leonardou et al., 2021). Such iterative experiences are important for young learners because they encourage experimentation and learning from mistakes in a low-risk environment (Russo et al., 2024). Unlike traditional paper-based exercises, digital simulations allow students to actively manipulate objects and observe the consequences of their actions, which may strengthen conceptual understanding and foster more flexible problem-solving strategies (Elofsson et al., 2016). Consequently, the observed improvement in WPS abilities may reflect not only increased procedural competence but also enhanced conceptual reasoning.

The significant gains observed in post-test scores highlight the potential of educational games to support primary-level students in acquiring foundational skills like addition and basic arithmetic. This aligns with prior research indicating that well-designed digital games can foster improved students' WPS (Dewolf et al., 2014; Naude et al., 2022). The findings of this study suggest that incorporating game-based learning strategies can be a valuable tool for educators aiming to enhance essential competencies in mathematics and develop students' problem-solving abilities effectively (Reinhold et al., 2020; Sun-Lin & Chiou, 2019). The present study also contributes to the growing literature on digital mathematics education by

addressing a gap related to the development of word problem-solving abilities among early primary school students. While previous studies have frequently reported improvements in mathematical achievement following digital game-based interventions, fewer studies have specifically examined WPS abilities within socioculturally meaningful simulation environments (Jensen & Skott, 2022; Vanbecelaere et al., 2020). The positive outcomes observed in this study suggest that combining game-based learning, digital simulations, and sociocultural contexts may provide a promising approach for supporting young learners' mathematical development.

CONCLUSION

This study demonstrates the effectiveness of The Adventure of Adit in the Fruit Store game as an innovative and engaging tool for enhancing first-grade students' WPS abilities in mathematics. The findings show that the use of the game-based interactive simulation led to significant improvements in students' problem-solving skills, as evidenced by the results of the Wilcoxon Signed Ranks Test ($Z = -10.380$, $p < 0.001$). These results support the potential of game-based learning to not only enhance cognitive skills but also to foster a more enjoyable and engaging learning experience for young learners. The use of a sociocultural game-based approach aligns with theories of learning that emphasise the importance of contextualised and interactive experiences in the development of mathematical understanding. By providing a dynamic, context-rich environment, The Adventure of Adit in the Fruit Store allowed students to engage actively with mathematical concepts, leading to improved problem-solving abilities. Additionally, the increased student engagement and enjoyment observed in this study highlight the broader potential of educational games in improving student motivation and participation in learning activities.

In conclusion, this study suggests that incorporating game-based learning tools, particularly those with interactive and sociocultural elements, can be a valuable addition to early mathematics education. The findings indicate that such learning environments can support the development of students' word problem-solving abilities while simultaneously promoting active engagement and meaningful participation in learning activities. By integrating mathematical concepts within familiar real-life contexts, game-based simulations may help young learners construct mathematical understanding in ways that are both accessible and relevant to their everyday experiences. This study also contributes to the growing body of literature on digital game-based learning by providing empirical evidence of the potential benefits of sociocultural game-based simulations in primary mathematics education. Future research could further explore the learning processes that occur during gameplay and examine the longer-term impact of these interventions on students' mathematical development across different educational contexts and grade levels.

Limitation and Future Direction

This study provides insights into students' learning progression within a game-based mathematics learning environment. Although the study employed repeated observations to capture changes in students' performance over time, the analysis focussed primarily on overall patterns of progression reflected in mean scores across measurement occasions. As a result, the findings highlight trends in learning development, while further analyses could provide additional insights into aspects such as the evolution of problem-solving strategies, conceptual development, and variations in individual learning trajectories. In addition, the study was conducted within a specific intervention period, and therefore, the longer-term impact of the learning experience was beyond its scope. Future research could extend this work by incorporating more fine-grained analyses of learning processes and by examining the sustainability of students' gains in word problem-solving abilities over time. Longitudinal investigations across different grade levels may also offer valuable insights into how continued engagement with game-based learning environments supports students' mathematical development and problem-solving competencies throughout their educational journey.

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