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RESEARCH ARTICLE

Effects of a Realistic Mathematics Education-Based Tablet Intervention on Second-Grade Addition Skills

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Abstract: This study investigated the effectiveness of a didactic intervention utilizing a custom-developed tablet application, grounded in Realistic Mathematics Education (RME) principles, on second-grade students' addition skills (numbers up to 100). A quasi-experimental design with pre-test/post-test control group structure was employed. The sample consisted of 189 second-grade students (aged 6.5-7.5 years) from four public primary schools in Attica, Greece, during the 2022-2023 school year. Participants were assigned to either an experimental group (N = 96), receiving the RME-based tablet intervention for five weeks, or a control group (N = 93), receiving traditional instruction. Mathematical proficiency was assessed using an adapted version of the Test of Early Mathematics Ability, Third Edition (TEMA-3). Results from paired samples t-tests revealed significant improvements from pre-test to post-test for both the experimental group and control group on overall mathematics scores. However, a Mixed Repeated Measures ANOVA demonstrated a significant Time × Group interaction effect, indicating that the experimental group's improvement significantly exceeded that of the control group. These findings suggest that integrating RME principles with custom-designed tablet applications can substantially enhance young learners' mathematical understanding.

Keywords: Realistic Mathematics Education, tablet-based learning, addition skills, primary education, educational technology

1 Introduction

The effective teaching of foundational mathematical skills, such as addition, in early primary education is paramount, as it lays the groundwork for future mathematical understanding and real-world problem-solving (Jordan et al., 2009; Fuson, 2020). Early numeracy skills serve as powerful predictors of later academic achievement across multiple domains (Claessens et al., 2009; Duncan et al., 2007), making the quality of initial mathematics instruction critically important. Traditional instructional methods, while valuable, often struggle to fully engage young learners and foster deep conceptual understanding and flexible strategy use (Van de Walle et al., 2018).

In response to these pedagogical challenges, Information and Communication Technologies (ICT) have emerged as promising tools for mathematics education, offering dynamic and interactive environments that can enhance learning outcomes (Papadakis et al., 2021; Svane et al., 2023). Tablet-based applications, in particular, have shown considerable promise due to their intuitive touch interfaces (Ricoy & Sanchez-Martinez, 2023). Simultaneously, pedagogical approaches like Realistic Mathematics Education (RME), which ground mathematical concepts in students' experiential realities, have shown considerable potential for making mathematics more meaningful and accessible (Van den Heuvel-Panhuizen & Drijvers, 2020).

The primary purpose of this study is to investigate the effectiveness of a didactic intervention, utilizing a custom-developed tablet application based on RME principles, in enhancing second-grade students' understanding of addition (up to 100), compared to traditional teaching methods. This research employs a quasi-experimental design to address the following research questions:

(1) Did the experimental group show a statistically significant improvement in addition skills from pre-test to post-test?

(2) Did the control group show a statistically significant improvement in addition skills from pre-test to post-test?

(3) Was the improvement in addition skills significantly greater for the experimental group compared to the control group?

This study addresses a notable gap in the existing literature by extending RME-based tablet research to second-grade students learning addition with numbers up to 100. While prior studies have demonstrated the effectiveness of RME-integrated mobile applications primarily in preschool and kindergarten settings (Zaranis et al., 2013; Papadakis et al., 2016, 2021), research targeting primary school arithmetic operations remains limited. The present study contributes three key innovations: (a) it focuses specifically on second-grade students, an age group underrepresented in RME-technology integration research; (b) it targets addition skills within an extended number range (up to 100), which presents greater cognitive demands than the smaller number operations typically studied; and (c) it implements a systematic alignment between the four RME levels of mathematization and the digital activity design, ensuring pedagogical coherence throughout the intervention.

2 Literature Review

2.1 Realistic Mathematics Education

Realistic Mathematics Education (RME) is a domain-specific instructional theory developed at the Freudenthal Institute in the Netherlands, based on Hans Freudenthal's view that mathematics should be connected to reality and relevant to children's experiences (Freudenthal, 1991). The approach emphasizes progressive mathematization through four levels: Situational, Referential, General, and Formal (Gravemeijer, 1994). Recent meta-analyses have confirmed RME's effectiveness in elementary education, with studies showing significant improvements in mathematical problem-solving and conceptual understanding (Fauzan et al., 2024; Sanal & Elmali, 2024). Research indicates that RME enhances not only cognitive achievement but also students' mathematical literacy and self-efficacy (Tong et al., 2020). A systematic literature review by Svane et al. (2023) found that supplemental time interventions using approaches like RME had larger average effects (g = 0.53) than curriculum-based interventions.

2.2 Tablet-Based Mathematics Interventions

The integration of tablet technology in early mathematics education has gained substantial empirical support in recent years. A meta-analysis by Aspiranti and Larwin (2021) examining 20 group design studies with 2,805 participants found that tablet-based math interventions provided moderate positive effects for student mathematics gains. Outhwaite et al. (2017) demonstrated strong immediate and sustained mathematics learning gains following tablet intervention with UK primary school children, with particularly beneficial effects for low-achieving students. Their subsequent randomized control trial (Outhwaite et al., 2019) confirmed that interactive apps can significantly raise early mathematical achievement. Schacter and Jo (2017) reported that preschoolers using tablet-based mathematics instruction showed significantly greater learning gains compared to control groups in a randomized controlled trial. Furthermore, research has shown that tablet interventions can reduce cognitive demands for children with weak memory skills and support inclusive learning environments (Pitchford et al., 2018).

2.3 Integration of RME and Mobile Technology

The convergence of RME principles with mobile technology represents a promising yet underexplored area. Papadakis et al. (2021) investigated teaching mathematics with mobile devices using the RME approach in kindergarten, finding that tablets combined with developmentally appropriate software based on RME substantially contributed to early childhood students' comprehension of numbers. Their earlier comparative study (Papadakis et al., 2016) demonstrated that teaching with tablets compared to computers contributed significantly more to the development of children's mathematical ability. Zaranis et al. (2013) pioneered research on using mobile devices for teaching realistic mathematics in kindergarten education using MIT App Inventor. Building on this foundation, Zaranis et al. (2015) demonstrated the effectiveness of ICT-based instruction grounded in RME principles for teaching addition to first-grade students in the Greek educational context, while a parallel study confirmed similar benefits for subtraction instruction (Zaranis et al., 2015b). This body of work provided foundational evidence for technology-enhanced arithmetic instruction in primary schools. More recently, Skordialos (2024a) highlighted the potential of ICT integration and interactive boards for enhancing mathematics education in Greek primary schools, and further research explored the integration of ICT with the Van Hiele model for geometry education (Skordialos, 2024b). The visual block-based programming environment of MIT App Inventor has been widely used for creating educational applications, enabling even those without programming experience to develop functional mobile apps (Patton et al., 2019). However, most existing studies focus on preschool or kindergarten populations, leaving a gap in research specifically addressing tablet-based RME interventions for primary school addition skills.

3 Materials and Methods

3.1 Research Design

This study employed a quasi-experimental design with a pre-test/post-test control group structure (Shadish et al., 2002) to evaluate the effectiveness of a tablet-based didactic intervention, grounded in RME principles, on second-grade students' addition skills. The experimental group received the RME-based tablet intervention, while the control group was taught the same mathematical content using traditional teaching methods. This design was chosen to allow for comparisons of learning gains both within and between the two groups in a real-world school setting (Cohen et al., 2018; Fraenkel et al., 2018). (see Figure 1)

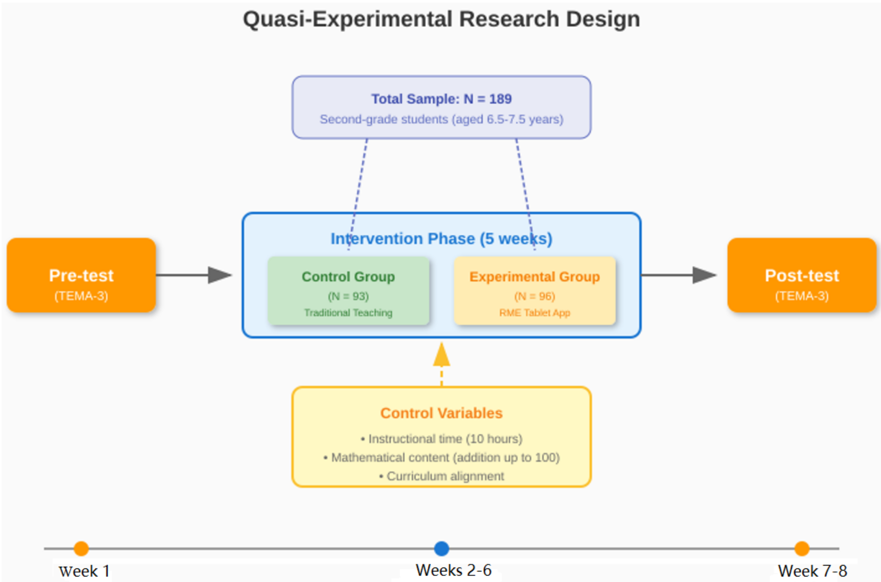

Figure 1 Quasi-experimental research design illustrating the pre-test/post-test control group structure. Both groups (N = 189) were assessed using the adapted TEMA-3 before and after the 5-week intervention phase. Control variables including instructional time, mathematical content, and consistency with the national curriculum were maintained across conditions.

3.2 Participants

The sample consisted of 189 second-grade students (aged 6.5-7.5 years) from four public primary schools in urban and suburban areas of Attica, Greece, during the 2022-2023 school year. Participants comprised 98 boys (51.9%) and 91 girls (48.1%). Eight intact second-grade classes were selected, Classes were then assigned at the cluster level to either the experimental condition (N = 96 students; 50 boys, 46 girls) and four to the control group (N = 93 students; 48 boys, 45 girls).

Initial equivalence checks using chi-square tests indicated no statistically significant differences between groups in terms of gender distribution ($\chi^2(1) = 0.05$, $p = 0.828$), prevalence of identified learning disabilities ($\chi^2(1) = 0.13$, $p = 0.715$), or primary language spoken at home ($\chi^2(1) = 0.21$, $p = 0.645$). An independent samples t-test confirmed no significant difference in pre-test mathematics scores, $t(187) = 0.42$, $p = 0.673$, $d = 0.06$, establishing baseline equivalence. Ethical approval was obtained from the Greek Institute of Educational Policy.

3.3 Instrument

Students' mathematical proficiency was assessed using an adapted version of the Test of Early Mathematics Ability, Third Edition (TEMA-3; Ginsburg & Baroody, 2003). The TEMA-3 is a widely used, norm-referenced, individually administered measure designed to assess the mathematics performance of children aged 3 years 0 months through 8 years 11 months. It has demonstrated high reliability (internal consistency coefficients ranging from 0.92 to 0.96) and strong validity, including content validity, criterion-related validity, and construct validity (Bliss, 2006; Yao et al., 2016).

3.3.1 Adaptation Process

For the purposes of this study, the TEMA-3 was adapted to focus specifically on numbers up to 100 and the operation of addition, in accordance with the second-grade Greek national mathematics curriculum. The adaptation process involved: (a) translation of items into Greek by two bilingual mathematics education experts, (b) back-translation verification, (c) cultural adaptation of context-specific items to reflect Greek students' experiences, and (d) pilot testing with 45 second-grade students not included in the main study to ensure clarity and age-appropriateness. Items that showed poor discrimination or were culturally inappropriate were revised or replaced.

3.3.2 Test Structure

The adapted test comprised 48 closed-ended items organized into three subscales of 16 items each: (a) Number Sequence–assessing students' ability to count forward and backward, identify missing numbers in sequences, and understand ordinal positions; (b) Number Perception–measuring magnitude comparison, place value understanding, and number recognition; and (c) Addition–evaluating computational fluency, word problem solving, and application of addition strategies.

Items within each subscale were distributed across the four RME-based levels of mathematical abstraction: Situational (contextualized problems with concrete scenarios), Referential (problems using visual models and representations), General (problems requiring pattern recognition and strategy application), and Formal (abstract symbolic problems). Each level contained 4 items per subscale, yielding 12 items per RME level across the entire test. Items were scored dichotomously (1 = correct, 0 = incorrect), with total scores ranging from 0 to 48.

3.3.3 Reliability Analysis

Internal consistency reliability was assessed using Cronbach's alpha coefficient. The adapted instrument demonstrated high reliability for the total score at both pre-test ($\alpha = 0.88$) and post-test ($\alpha = 0.89$). Subscale reliabilities were also acceptable: Number Sequence (pre-test $\alpha = 0.81$, post-test $\alpha = 0.83$), Number Perception (pre-test $\alpha = 0.79$, post-test $\alpha = 0.82$), and Addition (pre-test $\alpha = 0.84$, post-test $\alpha = 0.87$). These values indicate that the adapted TEMA-3 provided consistent and reliable measurement of students' mathematical abilities.

3.4 Intervention

The didactic intervention lasted for five weeks, with approximately two teaching hours (90 minutes total) per week, resulting in approximately 10 hours of instructional time.

3.4.1 Experimental Group

Students (N = 96) were taught addition using a custom-designed educational application on Android tablets developed using MIT App Inventor 2. The application was grounded in RME principles, featuring activities structured across the four RME levels (Situational, Referential, General, and Formal), incorporating realistic scenarios, interactive elements, and immediate feedback. Students worked in small, heterogeneous groups of 3-4 students to foster collaborative learning grounded in sociocultural theory (Vygotsky, 1978).

Application Design and Features. The application featured an engaging underwater cartoon-themed environment with fictional sea characters serving as guides throughout the mathematical activities. This thematic choice was intentional, as research suggests that familiar and appealing characters can enhance young learners' motivation and engagement with educational content. The visual design incorporated vibrant colors (bright yellows, blues, greens, and pinks), animated sea creatures, bubbles, underwater plants, and coral reef backgrounds to create an immersive and visually stimulating learning environment.

3.4.1.1 Activity Structure and Content

The application comprised 24 distinct activities organized into four modules reflecting the RME levels. At the Situational level (6 activities), students engaged with contextual problems embedded in realistic underwater scenarios, such as counting fish, collecting shells, or helping animated character deliver Krabby Patties. The Referential level (6 activities) introduced visual models including number lines, ten-frames, and grouping representations using sea-themed manipulatives. The General level (6 activities) focused on developing mental calculation strategies and number relationships through pattern recognition and skip counting exercises. Finally, the Formal level (6 activities) presented symbolic arithmetic problems with decreasing visual support, transitioning students toward abstract mathematical thinking. (see Figure 2)

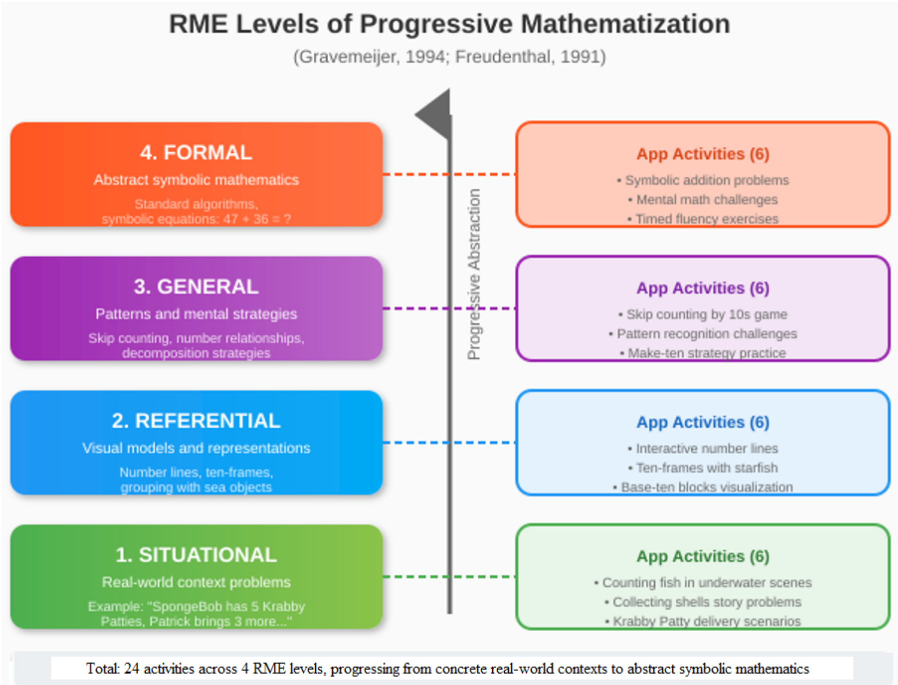

Figure 2 The four levels of progressive mathematization in Realistic Mathematics Education (RME) and related application activities. The tablet application included 24 activities (6 per level) progressing from concrete real-world contexts (Situational) through visual models (Referential) and mental strategies (General) to abstract symbolic mathematics (Formal).

Each activity targeted specific mathematical competencies: number sense and magnitude comparison (8 activities), addition with single-digit numbers (8 activities), and addition with two-digit numbers up to 100 (8 activities). Activities incorporated multiple interaction modalities including drag-and-drop manipulation of objects, tap-to-select responses, and number input via an on-screen keypad designed with large, child-friendly buttons.

3.4.1.2 Progressive Difficulty and Feedback System

The application implemented a carefully calibrated progressive difficulty system. Within each activity, problems were sequenced from simple to complex, beginning with smaller numbers and fewer steps before advancing to larger numbers and multi-step problems. For example, addition activities progressed from single-digit addends (e.g., 3 + 4) to double-digit numbers without regrouping (e.g., 23 + 15) and finally to problems requiring regrouping (e.g., 47 + 36). Students were required to achieve 80% accuracy on each activity level before unlocking subsequent levels, ensuring mastery before progression.

The immediate feedback system was a central pedagogical feature. Correct responses triggered positive reinforcement through animated celebrations (e.g., animated characters celebrating, bubbles floating upward, sea creatures spinning), encouraging sounds, and verbal praise in Greek (e.g., "Μπράβο!" [Well done!], "Συνέχισε έτσι!" [Keep it up!]). Incorrect responses prompted supportive corrective feedback without negative consequences–characters would gently shake their heads, and the application provided hints or visual scaffolding to guide students toward the correct answer. Students could attempt each problem multiple times, promoting a growth mindset and reducing mathematics anxiety. (see Figure 3)

One representative activity focused on number sense development, where students practiced counting by tens (skip counting) to reach 100. In this activity, students navigated through an underwater maze, tapping on fish displaying multiples of ten in the correct sequence while

Figure 3 Second-grade students engaged in collaborative tablet-based mathematics activities during the intervention phase. Students worked in small groups, interacting with the custom-developed application featuring the underwater cartoon theme.

avoiding "trap" fish showing incorrect numbers. This activity corresponded with the Situational level of RME, presenting mathematics within a meaningful, game-based context that maintained high engagement. (see Figure 4)

Figure 4 Screenshot of the custom-developed tablet application showing a number sense activity. Students practice counting by tens to 100 in an underwater-themed game environment. The Greek text instructs students to "Reach 100 by counting by 10s while avoiding the traps." Navigation buttons (Previous/Next) allow students to progress through activities at their own pace.

3.4.2 Control Group

Students (N = 93) were taught the same mathematical content by their regular classroom teachers using traditional teaching methods: instruction based on the official Greek school textbook, teacher-led explanations, and standard paper-and-pencil exercises.

3.5 Procedure

The study was conducted over an eight-week period during the first semester of the 2022-2023 academic year, following a structured three-phase design. The intervention phase lasted five weeks within an eight-week study period.

3.5.1 Phase 1

Pre-test Assessment (Week 1). The adapted TEMA-3 was administered to all 189 participants approximately 10 days before the intervention commenced. Testing was conducted individually by trained research assistants in a quiet room within each school during regular school hours. Each assessment session lasted approximately 25-35 minutes. Standardized administration procedures were followed, with all instructions provided verbally in Greek. Students were informed that the test was not graded and would not affect their school marks, to minimize test anxiety.

3.5.2 Phase 2

Intervention (Weeks 2-6). The five-week intervention was implemented during regular mathematics instruction time. Both groups received instruction on the same mathematical content (addition with numbers up to 100) as specified in the Greek national curriculum, ensuring content equivalence. The experimental group participated in tablet-based activities using the custom-developed application for approximately 90 minutes per week (two 45-minute sessions), facilitated by the classroom teacher and one research assistant. The control group received traditional teacher-led instruction using the official Greek mathematics textbook, worksheets, and conventional manipulatives (e.g., base-ten blocks, counters) for equivalent instructional time. Teachers in both conditions followed detailed lesson plans to ensure consistency in content coverage and pacing.

3.5.3 Phase 3

Post-test Assessment (Weeks 7-8). The same adapted TEMA-3 instrument used in the pre-test was re-administered to all participants approximately 5 days after the conclusion of the intervention. Identical standardized administration procedures were followed. The same research assistants who conducted pre-testing administered post-tests to maintain consistency. To minimize potential testing effects, the order of items within each subscale was randomized for the post-test while maintaining equivalent difficulty distribution.

3.6 Data Analysis

Data were analyzed using IBM SPSS Statistics (Version 30). Paired samples t-tests were used to compare pre-test and post-test scores within each group. A Mixed Repeated Measures ANOVA was conducted with Time (pre-test, post-test) as the within-subjects factor and Group (experimental, control) as the between-subjects factor. Effect sizes were calculated using Cohen's d for t-tests (small: 0.2, medium: 0.5, large: 0.8) and partial eta squared for ANOVA (small: 0.01, medium: 0.06, large: 0.14). The significance level was set at $\alpha = 0.05$.

4 Results

4.1 Descriptive Statistics

Table 1 presents the descriptive statistics for total mathematics scores and subscale scores at pre-test and post-test for both groups. At pre-test, the groups demonstrated comparable performance across all measures, with mean total scores of 24.53 (SD = 6.21) for the experimental group and 24.12 (SD = 6.48) for the control group. This initial equivalence provides a solid foundation for between-group comparisons.

Examination of Table 1 reveals several noteworthy patterns. First, both groups showed improvement from pre-test to post-test, as expected following five weeks of mathematics instruction. Second, the magnitude of improvement differed substantially between groups: the experimental group's mean total score increased by 10.15 points (from 24.53 to 34.68), whereas the control group's mean increased by 5.78 points (from 24.12 to 29.90). Third, this differential improvement is particularly pronounced in the Addition subscale, where the experimental group improved by 4.17 points compared to 2.06 points for the control group. Fourth, standard deviations remained relatively stable across time points, suggesting that the intervention did not differentially affect score variability.

Table 1 Descriptive Statistics for Mathematics Scores by Group and Time

Variable	Exp. M	Exp. SD	Ctrl. M	Ctrl. SD
Total Score (max = 48)				
Pre-test	24.53	6.21	24.12	6.48
Post-test	34.68	5.94	29.90	6.35
Addition Subscale (max = 16)				
Pre-test	7.82	2.54	7.65	2.68
Post-test	11.99	2.31	9.71	2.58

Note: M = mean; SD = standard deviation; Exp. = Experimental (n = 96); Ctrl. = Control (n = 93).

4.2 Within-Group Comparisons (RQ1 and RQ2)

For the experimental group (RQ1), there was a statistically significant improvement from pre-test to post-test on the total mathematics score, $t(95) = -12.47$, $p < 0.001$, with a large effect size ($d = 1.27$). This indicates that the tablet-based RME intervention produced substantial gains in overall mathematical proficiency. Similarly, the Addition subscale showed significant improvement, $t(95) = -11.83$, $p < 0.001$, $d = 1.21$, demonstrating that the intervention was particularly effective for the target skill of addition. The mean improvement of 10.15 points on the total score and 4.17 points on the Addition subscale represents meaningful educational gains.

For the control group (RQ2), there was also a statistically significant improvement from pre-test to post-test on the total mathematics score, t(92) = -7.89, $p < 0.001$, d = 0.82. The Addition subscale likewise showed significant gains, t(92) = -6.54, $p < 0.001$, d = 0.68. These results confirm that traditional instruction also produced meaningful learning gains, which is expected given five weeks of focused mathematics instruction. However, as indicated by the smaller effect sizes compared to the experimental group (d = 0.82 *vs.* d = 1.27 for total score), the magnitude of improvement was notably less pronounced. The control group's mean improvement of 5.78 points on the total score was approximately 57% of the experimental group's improvement. (see Table 2)

Table 2 Paired Samples t-Test Results for Within-Group Comparisons

Group / Measure	Mean Diff.	SD Diff.	t	p	Cohen's d
Experimental (n = 96)					
Total Score	10.15	7.98	-12.47	< 0.001	1.27
Addition Subscale	4.17	3.45	-11.83	< 0.001	1.21
Control (n = 93)					
Total Score	5.78	7.06	-7.89	< 0.001	0.82
Addition Subscale	2.06	3.04	-6.54	< 0.001	0.68

Note: Mean Diff. = Post-test minus Pre-test mean; SD Diff. = Standard deviation of difference scores.

4.3 Between-Group Comparison: Mixed Repeated Measures ANOVA (RQ3)

To address Research Question 3, a Mixed Repeated Measures ANOVA was conducted. For the total mathematics score, there was a significant main effect of Time, F(1, 187) = 245.67, $p < 0.001$, partial $\eta^2 = 0.568$. There was also a significant main effect of Group, F(1, 187) = 14.23, $p < 0.001$, partial $\eta^2 = 0.071$. Critically, the Time × Group interaction was significant, F(1, 187) = 18.34, $p < 0.001$, partial $\eta^2 = 0.089$, indicating that the experimental group's improvement was significantly greater than the control group's.

For the addition subscale, similar patterns emerged: significant main effect of Time, F(1, 187) = 198.45, $p < 0.001$, partial $\eta^2 = 0.515$; significant main effect of Group, F(1, 187) = 16.78, $p < 0.001$, partial $\eta^2 = 0.082$; and significant Time × Group interaction, F(1, 187) = 14.56, $p < 0.001$, partial $\eta^2 = 0.072$. (see Table 3)

Table 3 Mixed Repeated Measures ANOVA Results for Total Mathematics Score

Source	df	MS	F	p	partial η^2
Between Subjects					
Group	1	1089.45	14.23	< 0.001	0.071
Error	187	76.54			
Within Subjects					
Time	1	5987.34	245.67	< 0.001	.568
Time × Group	1	447.12	18.34	< 0.001	0.089
Error (Time)	187	24.38			

At post-test, the experimental group significantly outperformed the control group on the total mathematics score, t(187) = 5.42, $p < 0.001$, d = 0.79, and the addition subscale, t(187) = 6.12, $p < 0.001$, d = 0.89, despite no significant differences at pre-test.

5 Discussion

This study investigated the effectiveness of a custom-developed tablet application, grounded in Realistic Mathematics Education (RME) principles, in enhancing second-grade students' addition skills compared to traditional teaching methods. The findings provide compelling evidence for the efficacy of this integrated technological-pedagogical approach.

Regarding Research Question 1, the experimental group demonstrated substantial improvement with large effect sizes (d = 1.27 for total score; d = 1.21 for addition), indicating meaningful practical impact on students' mathematical development. These findings correspond with previous research (Schacter & Jo, 2017; Outhwaite et al., 2019) and extend this literature by providing evidence specifically for RME-aligned tablet applications.

For Research Question 2, the control group also showed significant improvement, which is expected given five weeks of instruction on addition. However, the effect sizes for the control group (d = 0.82 for total score; d = 0.68 for addition) were substantially smaller than those of the experimental group.

Most critically, addressing Research Question 3, the significant Time × Group interaction effects (partial η^2 = 0.089 for total score; partial η^2 = 0.072 for addition) confirmed that the experimental group's learning gains significantly exceeded those of the control group. The experimental group improved by an average of 10.15 points, compared to 5.78 points for the control group–almost double the gain.

Several factors may account for these superior outcomes. First, the RME framework's emphasis on contextual, realistic problems likely enhanced engagement and facilitated meaningful connections between abstract mathematical concepts and students' experiential realities (Van den Heuvel-Panhuizen & Drijvers, 2020; Fauzan et al., 2024). The progressive mathematization process–moving from situational to formal understanding–may have scaffolded conceptual development more effectively than traditional approaches that often introduce abstract symbols prematurely.

Second, the tablet application's interactive features and immediate feedback system reflect principles of effective digital learning design (Cheung & Slavin, 2013). The instantaneous corrective feedback, combined with positive reinforcement for correct responses, may have accelerated skill acquisition by providing timely information about performance and maintaining motivation. Third, the integration of RME principles with mobile technology, as advocated by Papadakis et al. (2021), appears to create synergistic effects that enhance learning outcomes beyond what either approach achieves independently.

It is important to note that the controlled instructional time (90 minutes per week for both groups) and strict curriculum alignment ensured that observed differences can be attributed to the mode of instruction rather than differences in content coverage or time-on-task. Furthermore, the similar standard deviations across groups and time points suggest that the intervention did not produce ceiling effects or differential variability, strengthening confidence in the validity of the findings.

The present findings extend the existing literature on RME-based technology interventions in several important ways. Unlike previous studies that focused predominantly on preschool and kindergarten populations (Zaranis et al., 2013; Papadakis et al., 2016, 2021), this research demonstrates that the benefits of combining RME principles with tablet technology extend to primary school students working with more complex arithmetic operations. The systematic alignment between the four RME levels and the application's activity structure appears to be a critical design feature, ensuring that students progress through mathematization stages in a pedagogically coherent manner. This structured approach may explain why the observed effects were comparable to or larger than those typically reported in studies using educational applications with less explicit theoretical grounding.

6 Limitations and Future Directions

Several limitations should be acknowledged when interpreting these findings. First, the quasi-experimental design with cluster-level assignment, while appropriate for school-based research, does not allow for causal conclusions with the same certainty as individually randomized experiments. Although baseline equivalence was established on measured variables, unmeasured confounds at the classroom level (e.g., teacher experience, classroom climate) cannot be entirely ruled out.

Second, the relatively short duration of the intervention (five weeks) limits our understanding of long-term retention and transfer effects. While the immediate post-test results are encouraging, future research should include delayed follow-up assessments to examine whether gains are maintained over time.

Third, the study was conducted in a specific cultural and educational context (Greek public primary schools), which may limit generalizability to other settings. Fourth, while the effect sizes were substantial, the study did not include measures of student engagement, motivation, or attitudes toward mathematics. Future research should incorporate such measures to better understand the mechanisms through which tablet-based RME instruction produces its effects.

Future research directions include: (a) examining the effectiveness of similar interventions for other mathematical operations; (b) investigating whether certain subgroups benefit differentially from tablet-based RME instruction; (c) comparing different implementation models; and (d) conducting cost-effectiveness analyses to inform educational policy decisions.

7 Conclusion

This study provides empirical evidence that a tablet-based instructional intervention grounded in the principles of Realistic Mathematics Education can substantially enhance second-grade students' addition skills when compared with conventional classroom instruction. The experimental group achieved nearly double the learning gains relative to the control group, with consistently large effect sizes indicating not only statistical significance but also strong practical relevance in authentic classroom conditions. The findings suggest that the observed improvements are attributable to the coherent integration of pedagogical design and technology, rather than to the mere presence of digital tools. For educators, curriculum designers, and policy makers, the results highlight the pedagogical value of moving beyond generic uses of educational technology toward carefully designed digital interventions that are explicitly consistent with empirically validated instructional frameworks, such as RME, and that support conceptual understanding, strategic flexibility, and meaningful engagement with mathematical content.

Ethics Statement

Ethical approval was obtained from the Greek Institute of Educational Policy. Informed consent was obtained from all parents. Research procedures adhered to established ethical guidelines for educational research involving human participants (Petousi & Sifaki, 2020).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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