



Impact of an Android-Based Numeria Application on Students' Numeracy Skills in Inclusive Classrooms: A Quasi-Experimental Study

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Abstract

Numeracy skills are essential in elementary education, yet many students still struggle, particularly in inclusive classrooms. This study addresses the limited empirical evidence regarding the effectiveness of mobile-based mathematics learning applications in supporting numeracy development in inclusive classrooms, particularly for students with tendencies toward dyscalculia. This study aims to examine the impact of the Android-based Numeria application, which integrates a Realistic Mathematics Education (RME) approach, on elementary students' numeracy skills. A quasi-experimental pretest-posttest control group design was employed, involving 175 fourth-grade students from eight inclusive elementary schools in Central Java, Indonesia. Data were collected using a validated numeracy test and analyzed using normalized gain (N-gain), independent samples t-test, and Cohen's d effect size. The results indicate that the experimental group demonstrated significantly greater improvement in numeracy skills compared to the control group ($t = 2.20$, $p < 0.05$), with a small-to-moderate effect size ($d = 0.33$). Students with tendencies toward dyscalculia also showed greater improvement in the experimental group; however, the difference was not statistically significant, indicating a meaningful practical effect. These findings suggest that integrating mobile learning technology with an RME-based contextual approach can support more adaptive and interactive mathematics learning in inclusive settings. This study contributes empirical evidence on the role of Android-based learning applications in supporting numeracy development among students with diverse learning characteristics.

Keywords:

Numeracy skills; Android-based learning application; inclusive classrooms; Realistic Mathematics Education; dyscalculia

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INTRODUCTION

The development of digital technology has led to significant transformations in learning practices across diverse educational contexts. The integration of technology into learning enables the presentation of materials to be more interactive, flexible, and adaptive to students' learning needs (Jaafar et al., 2020; Suresh Babu et al., 2025; Zoubir et al., 2026). In mathematics learning, the use of digital technology has the potential to facilitate the understanding of abstract concepts among students through visualizations, interactive exercises, and direct feedback, which are difficult to provide in conventional learning (Wang & Wang, 2024; Yohanes Ruamba et al., 2025).

One essential competency in mathematics learning is numeracy. Numeracy encompasses the ability to perform calculations, along with the capacity to understand quantitative information, interpret mathematical representations, and apply mathematical concepts in everyday life (Grotlüschen et al., 2020; Jain & Rogers, 2019; Raharjo et al., 2025). However, previous studies indicate that elementary school students' numeracy skills still face significant challenges, particularly in understanding number relationships, performing basic arithmetic operations, and solving contextual problems that require reasoning (Kristesia et al., 2025; Rufiana et al., 2025; Syamsuddin et al., 2025).

These issues become more complex in inclusive classroom contexts, where students experience diverse learning needs and challenges, including those associated with dyscalculia. Dyscalculia is a specific learning difficulty characterized by difficulties in processing numerical information and understanding mathematical concepts (Landerl et al., 2021; Stasolla et al., 2025). Students with dyscalculia generally experience difficulties understanding the relationships between numbers, performing basic arithmetic operations, and solving numerical problems that involve reasoning (Everatt et al., 2013).

In this context, digital-based learning technology, particularly Android-based mobile applications, offers the opportunity to create a more adaptive learning environment. Learning applications enable students to learn independently, control their learning pace, and receive immediate feedback during the learning process (Hardiyanti et al., 2024; Juhanaini et al., 2025; Rosmayanti et al., 2025). Furthermore, the use of digital media has been shown to increase student engagement, facilitate visualization of mathematical concepts, and support the development of problem-solving skills (Al-barakat et al., 2025; Dong, 2025; González-Mendes et al., 2026; Payung & Sukjaya Kusumah, 2025). However, most research still focuses on improving mathematics learning outcomes in general and has not specifically examined the effectiveness of digital learning applications in supporting the numeracy skills of students with mathematics learning difficulties in inclusive classroom contexts. Therefore, examining the effectiveness of technology-based learning specifically within inclusive classrooms is essential.

In addition to technology, pedagogical approaches also play a crucial role in supporting understanding of numeracy concepts. One widely used approach in mathematics learning is Realistic Mathematics Education (RME). This approach emphasizes using real-world contexts as a starting point for learning, allowing students to construct mathematical understanding through meaningful activities (Fauzan et al., 2024; Revina & Leung, 2019; Yilmaz, 2020).

The integration of digital technology and the RME approach offers opportunities to create more context-rich, interactive mathematics learning. Digital applications enable the visual and dynamic simulation of real-life contexts, thereby facilitating the understanding of numeracy situations among students that are difficult to explain using conventional methods (Sakurai & Goos, 2023; Valero Larico et al., 2026).

Despite the growing integration of digital technology in mathematics education, its effectiveness in supporting numeracy development in inclusive classrooms remains insufficiently explored. In particular, there is limited empirical evidence regarding the extent to which mobile-based learning applications are able to accommodate students with diverse learning characteristics, especially those exhibiting tendencies toward dyscalculia. Existing studies tend to focus on general student populations and often overlook the specific challenges faced by students with numeracy learning difficulties in inclusive settings.

To further elucidate these limitations, several critical gaps are identified. First, limited studies have employed rigorous quasi-experimental designs to examine the effectiveness of mobile-based learning applications specifically in inclusive classroom

settings. Second, existing studies rarely focus on students with dyscalculia tendencies as a distinct subgroup, resulting in a lack of empirical evidence on how digital learning environments can support their numeracy development. Third, the integration of the Realistic Mathematics Education (RME) approach within mobile learning applications has not been sufficiently explored, particularly in terms of its impact on students' conceptual understanding in diverse learning contexts. Addressing these gaps is essential for advancing understanding of how technology-enhanced learning is designed to support inclusive and equitable mathematics education.

Building upon these gaps, this study advances the literature by integrating mobile learning technology with an RME-based contextual approach to support numeracy development in inclusive classrooms. Unlike prior studies, this research specifically focuses on students with diverse learning characteristics, including those with tendencies toward dyscalculia, within a quasi-experimental framework.

To address these gaps, this study aims to examine the impact of the Android-based Numeria application, which integrates the RME approach, on elementary students' numeracy skills in inclusive classroom contexts. This study provides empirical evidence on the systematic design of technology-enhanced learning environments to support inclusive mathematics education and improve numeracy outcomes for students with diverse cognitive characteristics. To achieve this objective, the study addresses the following research questions:

1. Is there a significant difference in numeracy skill improvement between students using the Numeria application and those receiving conventional instruction in inclusive classrooms?
2. To what extent does the use of the Numeria application influence students' numeracy skill development?
3. Does the application differentially impact students with tendencies toward dyscalculia compared to conventional learning?

This study contributes to the literature by providing empirical evidence from an inclusive classroom context using a quasi-experimental design, thereby offering practical and theoretical insights into the integration of RME-based mobile learning for diverse learners.

METHODS

Research Design

This study employed a quasi-experimental design with a pretest-posttest control group (Muse & Baldwin, 2021). The present research adopts this design to investigate the effect of an Android-based mathematics learning application (Numeria) on students' numeracy skills in an inclusive classroom context, by comparing learning outcomes between the experimental and control groups.

In this design, two groups of students with relatively similar initial characteristics were given different treatments. The experimental group received mathematics instruction using the Numeria application, while the control group received conventional classroom instruction by the teacher. Before treatment, both groups were administered a pretest to assess students' initial numeracy skills. After the learning process was completed, both groups received a posttest to measure changes in students' numeracy skills following the intervention.

Experimental group	: $O_1 - X - O_2$
Control group	: $O_1 - - O_2$

Note:

O₁ = pretest

O₂ = posttest

X = treatment in the form of using the Numeria application

To ensure internal validity, initial ability equivalence between the experimental and control groups was assessed using pretest scores. Furthermore, learning conditions in the two groups were controlled by standardizing the instructional material, learning duration, and question difficulty, thereby enabling more accurate attribution of differences in learning outcomes to the use of the Numeria application.

Research Participants

It is better to replace it with: Participants were recruited through purposive sampling, based on criteria aligned with the research objectives, including the implementation of inclusive classroom practices, comparable grade levels, and a standardized curriculum across schools. Participants in this study consisted of 175 fourth-grade students from eight elementary schools implementing inclusive classrooms in Central Java, Indonesia.

Of the total participants, 124 students were categorized as regular students, while 51 students were identified as having dyscalculia tendencies. Identification of students with dyscalculia tendencies was based on a combination of classroom teacher recommendations, previous academic evaluations, and Colored Progressive Matrices (CPM) test results, which provided an overview of students' cognitive abilities. This classification aimed to identify students who experienced difficulties with numeracy learning in the classroom and was not intended to serve as a clinical diagnosis of dyscalculia.

The participants were then divided into two groups: an experimental group and a control group. The experimental group consisted of 88 students (62 regular students and 26 students with dyscalculia tendencies), while the control group consisted of 87 students (62 regular students and 25 students with dyscalculia tendencies). Group assignment was based on the equivalence of student numbers and the proportion of students with dyscalculia tendencies within each group, thereby enabling a more objective comparison of learning outcomes.

The relatively balanced distribution of participants between the two groups is expected to minimize initial bias and support the validity of the research results in evaluating the effect of using the Numeria application on students' numeracy skills in an inclusive classroom context. It is important to note that this classification does not constitute a formal clinical diagnosis of dyscalculia but rather serves as an operational categorization for research purposes.

Research Instruments

This study used a numeracy skills test and structured interviews. The numeracy test consisted of 10 items measuring number sense, arithmetic operations, and contextual problem solving. The test was administered as a pretest and posttest to identify changes in students' numeracy skills. The instrument's content validity was assessed through evaluations by mathematics education experts and elementary school teachers, and its reliability was evaluated using Cronbach's alpha to assess internal consistency.

The numeracy test items were developed based on key indicators of elementary-level numeracy skills, including number sense, arithmetic operations, and contextual problem solving. Each item was designed to reflect real-life situations aligned with the principles of the Realistic Mathematics Education (RME) approach. Content validity was evaluated by three experts in mathematics education using a content validity index (CVI),

resulting in a high level of agreement. The reliability of the instrument, measured using Cronbach's alpha, indicated acceptable internal consistency ($\alpha > 0.70$).

Furthermore, structured interviews were conducted to gather supporting data on students' learning experiences with the Numeria application, particularly regarding conceptual understanding and engagement in learning.

Research Procedure

This study was conducted in three stages: preparation, implementation, and evaluation. In the preparation stage, the Android-based mathematics learning application Numeria and the research instruments were developed. The main interface of the Numeria application is presented in Figure 1. The interface features a contextual learning environment based on everyday scenarios, such as shopping activities, with interactive menus, visual representations, and problem-solving tasks designed to support students' numeracy development.



Figure 1. Numeria App Interface

During the implementation stage, the experimental group received instruction using the Numeria application, while the control group followed conventional classroom instruction. The intervention was conducted over four sessions with equivalent materials and duration for both groups. Students' numeracy skills were assessed before and after the intervention to measure learning improvement.

In the evaluation stage, numeracy test data were collected and analyzed. In addition, limited interviews were conducted with students in the experimental group to obtain supporting information regarding their learning experiences. The overall research procedure is illustrated in Figure 2.

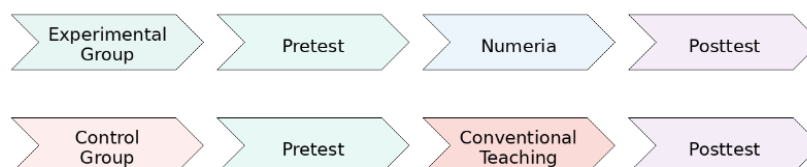


Figure 2. Research procedure in the Present Study

Data Analysis

The research data were analyzed using quantitative and qualitative approaches. Quantitative data obtained from the numeracy skills test were analyzed to measure student improvement after the treatment. Improvement in numeracy skills was calculated using normalized gain (N-gain) based on pretest and posttest scores for each group. Furthermore, to test for differences in numeracy skill improvement between the experimental and control groups, an independent samples t-test was used. Prior to this test, assumption tests were conducted. Normality was tested using the Shapiro-Wilk test, and homogeneity of variance was tested using Levene's test. The significance level used in this study was 0.05. To determine the magnitude of the effect of using the Numeria application on students' numeracy skills, Cohen's d was used to calculate the effect size. Interpretation of effect size values refers to Cohen's criteria, which classify effects into small, medium, and large categories. In addition, qualitative data from interviews were analyzed descriptively to

provide supporting information on students' learning experiences with the Numeria application in an inclusive learning context.

RESULTS & DISCUSSION

Results

Differences in Numeracy Skill Improvement Between Groups

The distribution of study participants is presented in Table 1. This study involved 175 students, consisting of 124 regular students (70%) and 51 students with dyscalculia tendencies (30%), who were divided relatively evenly between the control and experimental groups.

Table 1. Distribution of research participants

Group	Student Category	N	Percentage
Control	Regular Students	62	35%
	Dyscalculia Students	25	15%
Experimental	Regular Students	62	35%
	Dyscalculia Students	26	15%

Pretest results indicate that both groups had comparable initial numeracy skills. The mean pretest scores for the control group ($M = 43.46$; $SD = 7.34$) and the experimental group ($M = 43.39$; $SD = 7.71$) suggest that the groups were equivalent prior to the intervention (Table 2).

Table 2. Pretest comparison of numeracy skills

Group	N	Mean	SD
Control	87	43.46	7.34
Experimental	88	43.39	7.71

Following the intervention, both groups showed improvement in numeracy skills. However, the experimental group demonstrated higher posttest scores ($M = 64.94$; $SD = 4.79$) compared to the control group ($M = 61.11$; $SD = 13.94$), as shown in Table 3.

Table 3. Descriptive Statistics of Numeracy Scores

Group	Test	N	Mean	SD
Control	Pretest	87	43.46	7.34
Control	Posttest	87	61.11	13.94
Experimental	Pretest	88	43.39	7.71
Experimental	Posttest	88	64.94	4.79

Further analysis using gain scores revealed that the experimental group ($M = 21.56$; $SD = 11.03$) achieved greater improvement than the control group ($M = 17.66$; $SD = 14.02$) (Table 4).

Table 4. Gain Score of Students' Numeracy Skills

Group	N	Mean Gain	SD
Control Class	87	17.66	14.02
Experimental Class	88	21.56	11.03

The results of the independent samples t-test confirm that the difference in numeracy skill improvement between the two groups was statistically significant ($t = 2.20$; $p < 0.05$), indicating that the use of the Numeria application led to a significantly higher increase in numeracy skills compared to conventional learning (Table 5).

Table 5. Independent Sample t-test Results

Variable	t	p-value
Numeracy gain	2.20	0.030

The Extent of the Effect of the Numeria Application

To examine the magnitude of the effect of the Numeria application, an effect size analysis was conducted using Cohen's d. The results indicate an effect size of 0.33, which falls within the small-to-moderate category (Table 6).

Table 6. Effect Size of Numeria Application

Variable	Cohen's d	Interpretation
Numeracy skills	0.33	Small–Medium

This finding suggests that although the improvement in numeracy skills was statistically significant, the overall impact of the intervention was moderate.

Numeracy Skill Improvement in Students with Dyscalculia Tendencies

The analysis of students with dyscalculia tendencies shows that both groups experienced improvement in numeracy skills. However, the experimental group achieved higher posttest scores ($M = 60.92$; $SD = 4.66$) compared to the control group ($M = 57.00$; $SD = 9.67$), as presented in Table 7.

Table 7. Descriptive Statistics of Numeracy Scores for Students with Dyscalculia Tendencies

Group	N	Pretest Mean	SD	Posttest Mean	SD
Control	25	34.16	5.16	57.00	9.67
Experimental	26	33.92	4.57	60.92	4.66

Gain score analysis further indicates that students in the experimental group ($M = 27.00$; $SD = 6.84$) demonstrated greater improvement than those in the control group ($M = 22.84$; $SD = 11.99$) (Table 8).

Table 8. Gain Score of Students with Dyscalculia Tendencies

Group	N	Mean Gain	SD
Control	25	22.84	11.99
Experimental	26	27.00	6.84

However, the results of the independent samples t-test show that this difference was not statistically significant ($t = 1.51$; $p > 0.05$) (Table 9).

Table 9. Independent Sample t-test Results for Students with Dyscalculia Tendencies

Variable	t	p-value
Numeracy gain	1.51	0.138

Despite this, the effect size analysis reveals a moderate effect (Cohen's $d = 0.43$), suggesting that the Numeria application has practical potential in supporting numeracy development among students with dyscalculia tendencies (Table 10).

Table 10. Effect size of Numeria intervention for students with dyscalculia tendencies

Variable	Cohen's d	Interpretation
Numeracy skills	0.43	Medium

Discussion

Differences in Numeracy Skill Improvement Between Groups

The findings indicate that students who learned using the Android-based Numeria application demonstrated significantly greater improvement in numeracy skills compared to those who received conventional instruction. The observed improvement is attributable to the interactive and contextual features of the Numeria application. The improvement is supported by contextual and interactive features that promote active learning. result corroborates previous studies demonstrating that technology-enhanced learning environments enhance student engagement and conceptual understanding through visualization and interactivity (Wang & Wang, 2024; Yohanes Ruamba et al., 2025).

From a cognitive perspective, the use of contextual simulations helps reduce abstraction and supports meaning-making by linking mathematical concepts to familiar situations. This aligns with the principles of Realistic Mathematics Education (RME), which emphasize learning through meaningful contexts and progressive mathematization (Fauzan et al., 2024; Revina & Leung, 2019; Yilmaz, 2020). Such an approach is particularly relevant in inclusive classrooms, where students possess diverse cognitive characteristics and require varied instructional strategies.

The Extent of the Effect of the Numeria Application

Although the results show a statistically significant improvement in numeracy skills, the effect size was found to be in the small-to-moderate range. One possible explanation is the relatively short duration of the intervention, which may limit the extent to which students can fully internalize the learning experiences provided by the application. Additionally, the heterogeneity of student abilities in inclusive classrooms may moderate the overall effect, as students with different levels of prior knowledge and learning difficulties respond differently to the intervention.

Despite this, the findings remain meaningful in an educational context. Previous studies suggest that even moderate effects in real classroom settings are valuable, particularly when interventions are designed to support diverse learners and promote engagement (García et al., 2025; Wong & Yang, 2017; Yaseen et al., 2025). Therefore, integrating mobile learning and RME-based approaches is a promising direction for improving numeracy learning, especially when implemented over longer periods and supported by adaptive features.

Numeracy Skill Improvement in Students with Dyscalculia Tendencies

The findings related to students with dyscalculia tendencies show that although the improvement in numeracy skills was not statistically significant, the experimental group demonstrated higher gains and a moderate effect size. This suggests that the Numeria application has practical potential in supporting students with numeracy difficulties.

This result can be explained by the characteristics of digital learning environments, which allow students to learn at their own pace, repeat learning activities, and receive immediate feedback. Such features are particularly beneficial for students with dyscalculia tendencies, who often require more time and iterative learning experiences to understand mathematical concepts (Etherington et al., 2026; Zulpykhar et al., 2025).

Moreover, the contextual and visual nature of the Numeria application may help reduce cognitive barriers by transforming abstract numerical concepts into more concrete representations. This supports previous findings that digital and contextual learning can facilitate understanding and engagement among students with diverse learning needs (Hardiyanti et al., 2024; Rosmayanti et al., 2025).

However, the absence of statistical significance indicates that additional support mechanisms may be necessary to maximize the effectiveness of such interventions for students with learning difficulties. Future studies should explore adaptive and targeted support for this subgroup.

CONCLUSION

This study demonstrates that the use of the Android-based Numeria application, which integrates the Realistic Mathematics Education (RME) approach, contributes to a statistically significant improvement in elementary students' numeracy skills in inclusive classroom settings. Importantly, the results highlight the potential of mobile learning applications to facilitate more adaptive and inclusive mathematics instruction, especially for students with dyscalculia tendencies. While the improvement in this subgroup was not statistically significant, the observed practical effect suggests that such technology can provide additional learning support for students with mathematical learning difficulties. Future research is recommended to explore longer intervention durations, more robust identification of learning difficulties, and the integration of adaptive features to further enhance the effectiveness of digital learning applications in diverse educational contexts.

This study offers important implications for educational practice and research. Pedagogically, integrating mobile learning applications with a contextual approach such as Realistic Mathematics Education (RME) can support more adaptive and inclusive mathematics instruction through interactive learning, immediate feedback, and flexible pathways that accommodate diverse student needs. Practically, Android-based applications can extend learning beyond the classroom and promote student autonomy, particularly in inclusive settings requiring differentiated support. Theoretically, this study demonstrates that the RME framework can be effectively adapted within technology-enhanced learning environments. Finally, the findings highlight the need for more adaptive and personalized digital learning systems to better support students with diverse cognitive characteristics, including those with tendencies toward dyscalculia.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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