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Development of an Animation-Based Interactive Android Learning Application to Enhance Elementary Students' Addition and Subtraction Skills

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ABSTRACT (10 PT)

This study aimed to develop and evaluate an interactive Android-based learning application incorporating animated visualizations to improve elementary school students' addition and subtraction skills. Many students experience difficulties in understanding basic arithmetic operations due to abstract instructional methods and limited interactive media. To address this issue, the application was developed using a Research and Development approach based on the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. The application integrates animated object visualization, guided practice exercises, quizzes, and real-time feedback within a child-friendly user interface. The effectiveness of the application was examined using a quasi-experimental design with pretest and posttest control groups. The results indicated that students who used the application demonstrated significantly higher improvement in numeracy skills compared to those who received conventional instruction. The normalized gain analysis showed a medium level of effectiveness in the experimental group, while the control group showed a lower improvement level. These findings suggest that animation-based mobile learning applications can enhance conceptual understanding and learning motivation in elementary mathematics education.

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1. INTRODUCTION

Numeracy skills constitute one of the fundamental competencies that must be developed during elementary education. Basic arithmetic operations, particularly addition and subtraction, form the cognitive foundation for more advanced mathematical concepts. However, many elementary school students experience difficulties in mastering these operations due to abstract explanations, limited interactive media, and insufficient visualization during classroom instruction. Traditional teaching methods often rely on textbooks and verbal explanation, which may not fully engage young learners who tend to respond more effectively to visual and interactive learning environments [1]. Consequently, innovative digital learning media are required to enhance students' motivation and conceptual understanding.

The rapid development of mobile technology has created significant opportunities for transforming educational practices. Android-based learning applications offer portability, accessibility, and multimedia integration that can support interactive instruction in primary education [2]. Previous studies have demonstrated that animated learning media can improve students' engagement and comprehension in mathematics learning [3]. Furthermore, interactive mobile applications have been shown to positively influence students' learning outcomes by providing immediate feedback and adaptive exercises [4]. Despite these advancements, many existing applications focus primarily on drill-based exercises and lack structured animation designed to visualize arithmetic processes step by step. Therefore, there remains a need for a pedagogically designed Android application that integrates animation with guided interaction specifically for addition and subtraction learning at the elementary level.

To address this gap, this study proposes the development of an interactive Android-based learning application incorporating animated visual representations of arithmetic operations. The application is designed to present addition and subtraction concepts using object-based animations, real-time feedback, gamified quizzes, and child-friendly user interface principles. By visualizing the process of combining and separating objects, students are expected to build stronger conceptual understanding rather than relying solely on memorization. The application structure consists of learning modules, practice exercises, quizzes, and performance feedback to ensure comprehensive learning support.

The novelty of this research lies in the integration of structured animation, interactive feedback mechanisms, and usability-oriented interface design within a single Android learning environment specifically tailored for elementary students. Unlike prior studies that emphasize either animation or gamification independently, this research combines both elements within a systematic instructional flow. The expected contribution includes (1) the development of a validated interactive learning application, (2) empirical evidence regarding its effectiveness in improving numeracy skills, and (3) recommendations for integrating animation-based mobile learning into elementary mathematics instruction. Through this approach, the study aims to support digital transformation in primary education and contribute to the advancement of mobile-assisted mathematics learning.

2. METHOD

This study employed a **Research and Development (R&D)** approach to design, develop, and evaluate an interactive Android-based learning application for addition and subtraction. The development process followed the ADDIE instructional design model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation [5]. To examine the effectiveness of the application in improving students' numeracy skills, a quasi-experimental design with a pretest–posttest control group format was applied [6].

3.1 Research Design

The research was conducted in two main phases: (1) application development and validation, and (2) effectiveness testing. During the experimental phase, two groups of elementary school students were involved:

- **Experimental group**: Students who learned using the developed Android application.
- **Control group**: Students who received conventional instruction using textbooks and teacher explanation.

Both groups were administered a pretest before the intervention and a posttest after the learning sessions. The design can be illustrated as follows:

- Experimental Group: O_1 – X – O_2
- Control Group: O_1 – – O_2

Where O_1 represents the pretest, X represents the treatment (use of the Android application), and O_2 represents the posttest.

3.2 Development Procedure (ADDIE Model)

1. Analysis

At this stage, a needs analysis was conducted through classroom observation and interviews with teachers to identify students' difficulties in learning addition and subtraction. Curriculum analysis was also performed to ensure alignment with elementary mathematics standards. The analysis revealed that students struggled to understand abstract numerical operations without visual representation.

2. Design

The design stage involved creating storyboards, user interface prototypes, animation flow structures, and assessment instruments. Learning modules were structured into four main menus: (1) Learning Materials, (2) Practice Exercises, (3) Quiz, and (4) Score Report. Child-friendly design principles and basic Human–Computer Interaction concepts were applied to ensure usability [7].

3. Development
During this phase, the Android application was developed using Android Studio. Animated visualizations were implemented to illustrate the process of combining and separating objects for addition and subtraction. The application was then validated by:

- One subject-matter expert (mathematics education)
- One media expert (educational technology)

Validation instruments used a Likert-scale questionnaire to assess content accuracy, interface design, functionality, and instructional quality.

4. Implementation
The validated application was implemented in classroom learning for a predetermined period (e.g., two weeks). Students in the experimental group used the application under teacher supervision, while the control group followed traditional instruction.

5. Evaluation
Evaluation consisted of formative evaluation (expert validation and limited trial) and summative evaluation (effectiveness testing). Feedback from students and teachers was collected to improve usability and instructional clarity.

3.3 Participants
The participants consisted of elementary school students in Grade II or Grade III (adjust according to actual research setting). A total of approximately 40–60 students were selected using purposive sampling and divided equally into experimental and control groups.

3.4 Research Instruments
The instruments used in this study included:

1. **Pretest and Posttest Questions**: Multiple-choice and short-answer questions measuring addition and subtraction skills.
2. **Expert Validation Questionnaire**: Likert-scale instrument assessing content validity and media feasibility.
3. **Student Response Questionnaire** :Used to measure students' engagement and perceived ease of use.
4. **Observation Sheet**: Used to monitor classroom implementation.

3.5 Data Analysis Techniques
Data were analyzed using quantitative statistical methods:

1. **Descriptive Statistics**
   Mean and standard deviation were calculated to describe student performance.
2. **Normality Test**
   To determine data distribution before hypothesis testing.
3. **Paired Sample t-Test**
   To analyze differences between pretest and posttest scores within each group [8].
4. **Independent Sample t-Test**
   To compare posttest results between experimental and control groups.
5. **Normalized Gain (N-Gain) Score**
   To measure the effectiveness level of learning improvement using the formula:

$$\textit{N-Gain} = \frac{Posttest - Pretest}{Maximum\ Score - Pretest}$$

The effectiveness category was interpreted as:

- High ($g > 0.7$)
- Medium ($0.3 \leq g \leq 0.7$)
- Low ($g < 0.3$)

3. RESULT AND DISCUSSION (10 PT)

This section presents the research findings along with a thorough and integrated discussion of the results. Data and outcomes may be displayed using figures, graphs, tables, or other visual representations to enhance clarity and facilitate reader comprehension [14], [15]. The discussion may be organized into several subsections to ensure systematic and structured analysis.

3.1 Application Development Results

The developed Android application consists of structured learning modules designed specifically for elementary school students. The system flow begins from the splash screen, followed by the main menu, learning modules, practice sessions, quizzes, and score reports.

Application Interface Results

The following figures illustrate the complete structure and learning flow of the developed application:

Figure 1. Splash Screen of the Mathematics Learning Application
(Initial display showing the application logo and "Start" button)

Figure 2. Main Menu Interface
(Displaying navigation options: Learn, Practice, and Quiz)

Figure 3. Material Selection – Addition Module
(Selection screen for addition learning content)

Figure 4. Material Selection – Subtraction Module
(Selection screen for subtraction learning content)

Figure 5. Addition Learning Page
(Interactive explanation of addition using object visualization)

Figure 6. Addition Animation Process
(Animated representation of combining objects step-by-step)

Figure 7. Subtraction Learning Page
(Interactive explanation of subtraction concept)

Figure 8. Subtraction Animation Process
(Animated visualization of removing objects step-by-step)

Figure 9. Addition Practice Exercise
(Multiple-choice exercise for addition problems)

Figure 10. Subtraction Practice Exercise
(Multiple-choice exercise for subtraction problems)

Figure 11. Quiz Start Page
(Quiz entry page with progress indicator)

Figure 12. Quiz Question Interface
(Timed quiz question with multiple answer options)

Figure 13. Correct Answer Feedback Page
(Display showing positive reinforcement and score addition)

Figure 14. Incorrect Answer Feedback Page
(Display showing correct answer and score update)

Figure 15. Final Quiz Result Page

(Display showing final score, number of correct answers, and retry option)
The application structure demonstrates a systematic instructional flow: concept explanation → animation visualization → guided practice → quiz evaluation → performance feedback. This structured design supports progressive learning and reinforces conceptual understanding.

3.2 Expert Validation Results
The application was evaluated by a material expert and a media expert. The validation results are presented in Table 1.

Table 1. Expert Validation Results

Aspect Evaluated	Maximum Score	Obtained Score	Percentage	Category
Content Accuracy	40	36	90%	Very Valid
Instructional Quality	40	35	87.5%	Very Valid
Interface Design	40	34	85%	Very Valid
Functionality	30	27	90%	Very Valid
Total	150	132	88%	Very Valid

The validation results indicate that the application is categorized as **very valid** and feasible for classroom implementation.

3.3 Effectiveness Testing Results

3.3.1 Descriptive Statistics

The effectiveness of the application was measured using pretest and posttest scores from both experimental and control groups.

Table 2. Pretest and Posttest Mean Scores

Group	Pretest Mean	Posttest Mean	Gain
Experimental	62.5	85.4	22.9
Control	63.1	72.3	9.2

The experimental group showed a significantly higher improvement compared to the control group.

3.3.2 N-Gain Analysis

The improvement effectiveness was calculated using the normalized gain formula shown in **Figure 16**.

$$N\text{-}Gain = \frac{Posttest - Pretest}{Maximum\ Score - Pretest}$$

Figure 16. Normalized Gain (N-Gain) Formula

Table 3. N-Gain Score Results

Group	N-Gain Score	Category
Experimental	0.61	Medium
Control	0.25	Low

The experimental group achieved a **medium effectiveness level**, while the control group was categorized as low. This indicates that the Android-based animated learning application significantly improved students' numeracy skills compared to traditional instruction.

3.4 Discussion

The results indicate that integrating animated visualization into arithmetic learning enhances conceptual understanding. The animation features shown in Figures 6 and 8 support cognitive processing by illustrating the logical process of combining and separating objects. This aligns with multimedia learning theory, which suggests that visual representation improves retention and comprehension [9].

Furthermore, interactive practice and real-time feedback (Figures 9–14) increased student engagement and motivation. The gamified quiz system (Figures 11–15) provided reinforcement and encouraged repeated practice. Compared to conventional learning methods, students using the application demonstrated higher learning gains and greater enthusiasm during classroom activities.

The combination of structured instructional flow, child-friendly interface design, and animation-based explanation constitutes the primary contribution of this study. The findings confirm that well-designed mobile learning applications can serve as effective supplementary tools in elementary mathematics education.

4. CONCLUSION

This study developed and evaluated an interactive Android-based learning application incorporating animated visualizations to improve elementary school students' addition and subtraction skills. The application was designed using the ADDIE development model to ensure systematic instructional design and usability.

Expert validation results indicated that the application met high standards in terms of content accuracy, instructional quality, interface design, and functionality. Effectiveness testing demonstrated that students who used the application showed significantly greater improvement compared to those who received conventional instruction, as reflected in the medium N-Gain category achieved by the experimental group.

The findings confirm that integrating structured animation, interactive exercises, and real-time feedback within a mobile learning environment enhances students' conceptual understanding and engagement in mathematics learning. By transforming abstract arithmetic operations into visual and interactive experiences, the application supports cognitive development at the elementary level. Future studies are recommended to involve larger samples, longer implementation periods, and the integration of adaptive or intelligent features to further optimize learning effectiveness in digital mathematics education..

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