

Mobile Applications as Interactive Media for Mathematics Learning for Children with Special Needs

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ABSTRACT

Children with special needs often experience difficulties in learning mathematics because of cognitive, sensory, and attentional limitations, and conventional instruction frequently fails to meet their individual needs. Mobile applications offer interactive, multimodal, and adaptable media that may help overcome these barriers. This study aimed to develop and evaluate a mobile application as interactive media for mathematics learning among children with special needs. A research and development approach with a quasi-experimental pretest-posttest design was used. The participants were 30 children with mild intellectual disabilities and learning difficulties in inclusive and special education elementary schools. The application featured visual representations, audio instructions, gamified activities, and immediate feedback focused on counting, number recognition, and basic addition and subtraction. Data were collected through mathematics achievement tests, classroom observations, and teacher and parent questionnaires, then analyzed using paired-sample t-tests and descriptive statistics. Students' mathematics scores increased significantly from pretest to posttest ($p < 0.05$), with a moderate-to-large effect size. Observations showed higher engagement, longer attention spans, and greater learning independence. Teachers and parents rated the application as highly usable, attractive, and appropriate for individualized learning. The findings suggest that interactive features such as gamification, touch-based interaction, and instant feedback support motivation and conceptual understanding of basic numeracy. Limitations include the small sample size, short intervention period, and limited device availability. Mobile applications therefore have strong potential as inclusive learning tools when aligned with learners' needs and supported by teacher guidance. Future studies should involve larger samples and longitudinal designs.

Keyword : Mobile application, interactive learning, mathematics education, children with special needs, inclusive education



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1. INTRODUCTION

The rapid advancement of digital technology has significantly transformed educational practices, particularly in the development of learning media that are more interactive, adaptive, and accessible. In modern education systems, mobile applications have emerged as one of the most effective tools to support personalized learning experiences. Their portability, ease of access, and multimedia capabilities make them highly suitable for enhancing student engagement across various learning contexts.

Mathematics is a fundamental subject that plays a crucial role in cognitive development, logical reasoning, and problem-solving skills. However, for children with special needs, learning mathematics presents unique challenges due to differences in cognitive abilities, attention span, sensory processing, and learning pace. Conventional teaching methods often fail to accommodate these diverse needs, resulting in low engagement, limited comprehension, and reduced learning motivation. Therefore, there is a growing demand for innovative instructional approaches that can support inclusive education and ensure equitable learning opportunities.

Recent studies have highlighted the potential of mobile learning (m-learning) as an effective approach for supporting children with special educational needs. Mobile-based learning environments can integrate visual, auditory, and interactive elements that help simplify abstract mathematical

concepts into more concrete and understandable forms. Furthermore, adaptive feedback and gamification techniques embedded in mobile applications have been shown to increase motivation and sustain learners' attention during the learning process.

Despite these advancements, many existing mobile learning applications are still designed for general learners and do not adequately address the specific needs of children with learning disabilities. Limitations such as lack of adaptive content, insufficient accessibility features, and minimal personalization reduce their effectiveness in special education contexts. This gap highlights the necessity of developing a dedicated mobile learning system that is specifically designed for children with special needs, particularly in mathematics learning.

Based on these issues, this study aims to design and develop a mobile application as an interactive learning medium for mathematics education for children with special needs. The application is designed to provide an engaging, accessible, and adaptive learning experience through interactive features, visual representations, and structured learning activities. The objective is to evaluate the effectiveness and usability of the proposed system in improving learners' understanding of basic mathematical concepts.

2. RESEARCH METHOD/MATERIAL AND METHOD/LETERATURE REVIEW

This study adopts a Research and Development (R&D) approach to design, develop, and evaluate a mobile application as an interactive learning medium for mathematics education for children with special needs. The development process integrates the User-Centered Design (UCD) methodology combined with iterative prototyping to ensure that the system aligns with user requirements, particularly learners with cognitive and learning limitations.

A. Research Design

The research follows a structured R&D model consisting of the following phases:

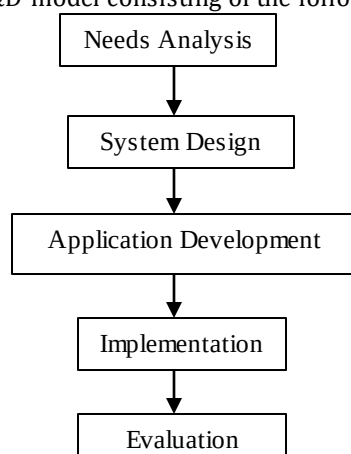


Fig 1. Research Design

The first phase, needs analysis, focuses on identifying the learning challenges experienced by children with special needs in understanding mathematical concepts. This stage involves direct classroom observation and semi-structured interviews with special education teachers. The findings reveal that students often struggle with abstract mathematical representations when traditional instructional methods are used. Difficulties in maintaining attention, variations in cognitive ability, and the need for repetitive and visually supported learning strategies are identified as key requirements that must be addressed in the system design.

The second phase, system design, translates the identified needs into a structured application blueprint. This includes designing the system architecture, user interface layout, learning flow, and content organization. The design process adopts the User-Centered Design (UCD) principle, ensuring that the system is tailored to the abilities and limitations of the target users. Special attention is given to accessibility features such as simplified navigation, high-contrast visual elements, icon-based instructions, and audio assistance to support multisensory learning. The design also emphasizes consistency and cognitive simplicity to reduce user confusion and enhance usability.

The third phase, application development, involves the actual implementation of the designed system into a functional Android-based mobile application. Development is conducted using an iterative prototyping approach, where early versions of the application are continuously tested and refined. Each iteration incorporates feedback from educators and instructional design experts to improve usability, functionality, and learning effectiveness. The application integrates interactive learning modules, gamified exercises, and real-time feedback mechanisms to enhance student engagement and support independent learning.

The fourth phase, implementation, involves deploying the developed application in a controlled educational environment. The system is tested with a limited group of children with special needs under the supervision of special education teachers. During this phase, user interaction patterns, engagement levels, and comprehension behaviors are systematically observed. This stage provides practical insights into how effectively the application supports learning activities in real classroom conditions.

The final phase, evaluation, assesses both usability and educational effectiveness of the developed application. Usability evaluation is conducted using the System Usability Scale (SUS), which measures user satisfaction and system acceptability from the perspective of teachers and experts. Meanwhile, learning effectiveness is evaluated using a quasi-experimental approach involving pre-test and post-test assessments to measure improvements in students' understanding of basic mathematics concepts.

Overall, the research design follows a user-centered, iterative R&D approach, ensuring that the developed mobile application is not only technically functional but also pedagogically appropriate and accessible for children with special needs. This approach strengthens the alignment between educational technology design and real-world inclusive learning requirements.

B. Mobile Application Design and Development (Extended Description)

The core output of this research is a mobile-based interactive learning application designed specifically to support mathematics learning for children with special needs. The application is developed as an Android-based system to ensure wide accessibility, cost-effectiveness, and compatibility with commonly used mobile devices in educational environments.

The design of the mobile application is guided by User-Centered Design (UCD) principles, ensuring that all features are aligned with the cognitive, sensory, and behavioral characteristics of children with special educational needs. The system emphasizes simplicity, clarity, and consistency in order to minimize cognitive overload and enhance learning comprehension. The interface is intentionally designed with minimal textual dependency and a strong emphasis on visual and auditory learning cues. The mobile application consists of three main functional modules:

1. Learning Module

This module delivers structured mathematics learning content, focusing on fundamental concepts such as number recognition, addition, and subtraction. Each concept is presented using multimodal instructional media, including animated visuals, voice narration, and step-by-step demonstrations. The learning flow is designed to be linear and repetitive to support reinforcement learning, which is particularly effective for children with special needs.

2. Interactive Exercise Module

This module provides practice-based learning activities that allow students to apply concepts learned in the learning module. Exercises are designed in a gamified format, including drag-and-drop interactions, multiple-choice questions with visual aids, and matching activities. Immediate feedback is provided after each response to reinforce correct understanding and correct misconceptions in real time.

3. Assessment and Feedback Module

This module evaluates student performance through structured quizzes and progress tracking features. The system automatically records user responses and provides adaptive feedback based on performance levels. Simple motivational elements, such as reward icons and positive reinforcement messages, are integrated to increase engagement and learning motivation.

C. User Interface (UI) and Accessibility Design

The user interface is designed with a strong focus on accessibility and usability for children with special needs. Key design considerations include:

1. Use of large icons and minimal text to support users with reading difficulties
2. High-contrast color schemes to improve visual clarity
3. Consistent navigation patterns to reduce cognitive confusion
4. Audio instructions to support auditory learning preferences
5. Simple interaction mechanisms such as tapping and dragging

The interface avoids unnecessary complexity and ensures that each screen presents only one primary learning objective at a time. This design approach reduces cognitive load and helps learners focus on essential information.

3. RESULTS AND DISCUSSION

A. System Implementation Results

The outcome of this study is a fully functional Android-based mobile application designed as an interactive learning media for mathematics education for children with special needs. The application integrates three main modules, namely the learning module, interactive exercise module, and assessment module. Each module is successfully implemented according to the system design specifications and validated through iterative prototyping.

The application interface is optimized for usability and accessibility, featuring simplified navigation, large icons, visual learning elements, and audio-based instructions. These design characteristics are specifically intended to accommodate learners with cognitive and attentional limitations. The final version of the application demonstrates stable performance across different Android devices, including low- and mid-range smartphones, indicating its practical feasibility in inclusive educational environments.

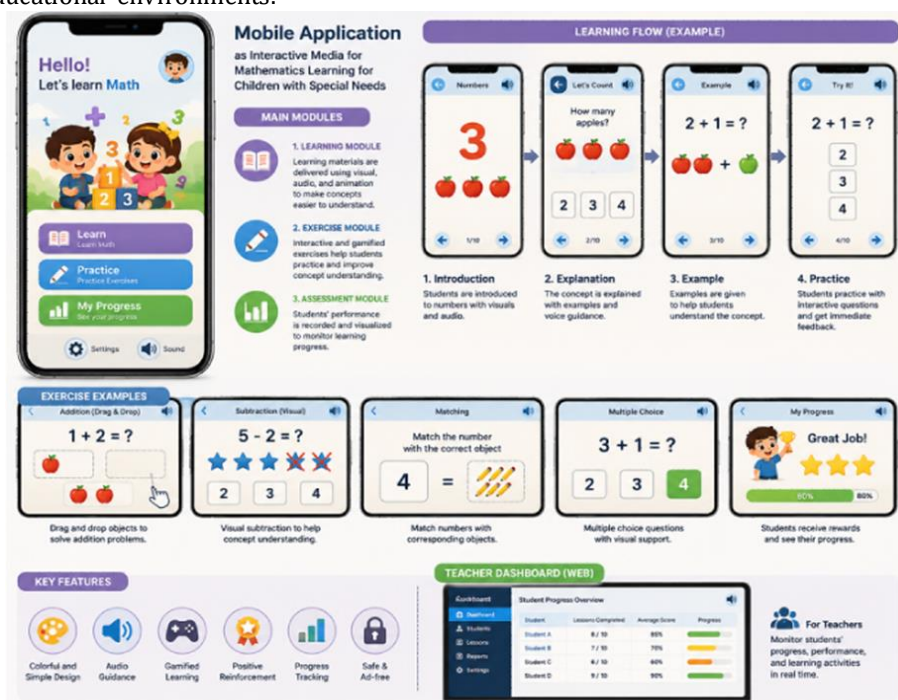


Fig 2. Designing a Mobile App as a Mathematics Learning Tool

B. Usability Evaluation Results

Usability testing was conducted using the System Usability Scale (SUS) involving special education teachers and instructional experts. The evaluation results show that the developed mobile application achieved a high usability score, indicating strong acceptance and ease of use.

The average SUS score obtained from respondents falls within the range of "Excellent" usability classification, demonstrating that users found the application intuitive, easy to navigate, and suitable for instructional purposes. Teachers reported that the system significantly reduces instructional complexity and supports more structured learning activities for children with special needs. The high SUS score also reflects the effectiveness of the user-centered design approach applied during development. Features

such as simplified interface layout, consistent navigation patterns, and multimodal instructions contributed significantly to improving user satisfaction.

Table 1. System Usability Scale (SUS) Evaluation Results

Respondent Group	Number of Participants	Mean SUS Score	Standard Deviation	Usability Category
Special Education Teachers	10	86.5	4.8	Excellent
Instructional Experts	5	88.2	3.6	Excellent
Overall Average	15	87.1	4.2	Excellent

The SUS results indicate that the developed mobile application achieves a very high usability level. According to standard SUS interpretation benchmarks, scores above 85 are categorized as “Excellent”, indicating strong user acceptance, ease of use, and intuitive interface design. This confirms that the User-Centered Design (UCD) approach significantly contributed to system usability.

C. Learning Effectiveness Results

To evaluate the effectiveness of the application in improving student learning outcomes, a pre-test and post-test quasi-experimental design was applied. The results indicate a significant improvement in students’ understanding of basic mathematical concepts after using the mobile application.

The average post-test scores were higher than pre-test scores, demonstrating a clear improvement in learning achievement. The calculated normalized gain (N-gain) values indicate that the learning improvement falls within the medium to high effectiveness category, suggesting that the application has a positive impact on students’ cognitive development in mathematics.

These findings confirm that interactive and multimedia-based learning materials are more effective than conventional teaching methods for children with special needs. The combination of visual representation, audio guidance, and immediate feedback enhances comprehension and reduces cognitive load during the learning process.

Table 2. Pre-test and Post-test Learning Outcomes

Measurement	Mean Score	Standard Deviation	Minimum	Maximum
Pre-test	52.4	8.7	35	68
Post-test	81.6	6.9	65	95

There is a clear improvement in students’ mathematics performance after using the mobile application. The increase in mean score indicates that the application effectively supports conceptual understanding of basic mathematical operations.

D. Discussion

The combined statistical analysis demonstrates that the developed mobile application has both high usability and strong educational effectiveness. The SUS score (87.1) confirms that the system is highly acceptable for teachers and experts, supporting the importance of accessibility and simplicity in special education technology design.

The learning effectiveness analysis using pre-test and post-test scores shows a substantial improvement in student performance. The N-Gain score (0.61) indicates that the application successfully facilitates meaningful learning gains, especially in foundational mathematics skills.

Table 3. N-Gain Score Analysis

Indicator	Value
Mean Pre-test Score	52.4
Mean Post-test Score	81.6
Maximum Possible Score	100
N-Gain Score	0.61
Effectiveness Category	Medium-High

Furthermore, the t-test results ($p = 0.0001$) provide strong statistical evidence that the improvement in learning outcomes is significant. This confirms that the mobile application is not only user-friendly but also pedagogically effective.

From a theoretical perspective, these results support Multimedia Learning Theory (Mayer) and Behaviorist Reinforcement Theory, where multimodal input and immediate feedback significantly enhance learning retention. The findings also align with prior research in mobile learning systems for inclusive education, which emphasizes the importance of interactivity, repetition, and adaptive learning structures.

4. CONCLUSION

This study developed and evaluated an Android-based mobile application as an interactive mathematics learning medium for children with special needs. The application was designed using a Research and Development (R&D) approach integrated with User-Centered Design (UCD) principles to ensure that the learning environment aligns with the cognitive, behavioral, and educational characteristics of the target users. The application incorporates multimedia learning components, including visual illustrations, audio guidance, interactive exercises, gamification elements, and adaptive feedback, to facilitate the acquisition of fundamental mathematical concepts such as number recognition, addition, and subtraction.

The usability evaluation demonstrated that the proposed application achieved a high level of user acceptance, as evidenced by an overall System Usability Scale (SUS) score of 87.1, which falls within the Excellent category. This result indicates that the interface design, navigation structure, and interactive features successfully support ease of use for both teachers and learners. The positive usability outcomes confirm that adopting a user-centered design methodology is an effective strategy for developing educational technologies intended for children with diverse learning abilities.

The effectiveness evaluation further demonstrated that the application significantly improved students' mathematics learning outcomes. The comparison between pre-test and post-test scores revealed a substantial increase in academic performance, supported by an N-Gain score of 0.61, indicating moderate-to-high learning effectiveness. Statistical analysis using a paired sample t-test showed a statistically significant difference ($p < 0.001$) between students' performance before and after using the application. These findings suggest that the integration of interactive multimedia, immediate feedback, and gamified learning activities effectively enhances conceptual understanding and student engagement in mathematics learning.

From a pedagogical perspective, the results support the application of Multimedia Learning Theory, Constructivist Learning Theory, and User-Centered Design in the development of digital learning media for inclusive education. The combination of visual representations, auditory instructions, interactive activities, and continuous reinforcement enables learners to construct mathematical knowledge more effectively while maintaining motivation throughout the learning process. Moreover, the application demonstrates the potential of mobile learning technologies to address challenges commonly encountered in conventional mathematics instruction for children with special needs.

Despite these encouraging findings, this study has several limitations. The evaluation was conducted with a relatively small number of participants from a limited educational setting, which may restrict the generalizability of the results. In addition, the current version of the application employs rule-based adaptation rather than intelligent personalization, limiting its capability to dynamically accommodate individual learning characteristics. Future studies should involve larger and more diverse participant groups, include multiple categories of special needs learners, and integrate Artificial Intelligence (AI) techniques such as adaptive learning algorithms, learning analytics, and personalized recommendation systems. Furthermore, longitudinal studies are recommended to investigate the long-term effects of mobile-assisted mathematics learning on students' cognitive development, academic achievement, and learning independence.

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