MENTAL MATH MOBILE APPLICATION

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ABSTRAK

Pembangunan Aplikasi Mudah Alih Matematik Mental bertujuan untuk menyediakan pendekatan inovatif dalam meningkatkan kecekapan aritmetik mental dalam kalangan pelajar, pendidik, dan individu umum. Aplikasi ini dibangunkan khusus untuk peranti Android dan direka bentuk dengan antara muka mesra pengguna, serta mengandungi maklum balas masa nyata dan perkembangan pembelajaran yang tersusun. Projek ini merangkumi modul utama seperti Latihan Aritmetik dengan pendekatan bertahap, Latihan Interaktif dengan kesukaran adaptif, dan Pertandingan Peringkat yang menggalakkan motivasi menerusi gamifikasi dan papan pendahulu. Melalui penggunaan teknologi Firebase dan pembangunan berasaskan Model Inkremental, aplikasi ini membolehkan penambahbaikan berterusan mengikut maklum balas pengguna. Java digunakan sebagai bahasa pengaturcaraan utama bagi menjamin prestasi dan skalabiliti sistem. Dengan menggabungkan unsur pendidikan dan teknologi digital, aplikasi ini berpotensi menjadi platform latihan matematik mental yang lebih berkesan, mudah diakses, dan menyeronokkan bagi meningkatkan pemikiran logik dan kecekapan numerik jangka panjang.

Kata Kunci: Matematik Mental, Gamifikasi, Aritmetik, Aplikasi Mudah Alih, Pembelajaran Digital

ABSTRACT

The development of the Mental Math Mobile Application aims to offer an innovative digital platform for enhancing mental arithmetic skills among students, educators, and individuals interested in improving numerical fluency. Targeted at Android devices, the application delivers a structured and interactive learning experience through real-time feedback, progressive difficulty levels, and engaging user interfaces. The app features key modules such as arithmetic training, interactive practice with adaptive difficulty, and competitive gameplay through a ranking system that fosters motivation via gamification. Many students face challenges in mastering mental arithmetic due to the lack of appealing and organized training tools. This project addresses the gap by combining technology and education in a mobile format that encourages frequent practice and logical thinking development.

The development process adopts the Incremental Development Model, enabling iterative improvements based on user feedback. Java is employed as the core programming language to ensure optimal performance and scalability. Overall, the Mental Math Mobile Application provides a practical and engaging solution for digital learning, making arithmetic practice more effective, accessible, and enjoyable across a wide range of users.

Keywords: Mental Math, Arithmetic, Gamification, Mobile Learning, Android Application

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INTRODUCTION

Mental math, the ability to perform arithmetic calculations mentally without relying on external tools like calculators or pen and paper, is a fundamental skill that enhances cognitive flexibility, memory, and problem-solving abilities (Olsen, 2015). This skill is indispensable in daily life, aiding in tasks such as shopping, budgeting, and time management. Research indicates that regular practice of mental math improves numerical fluency, logical thinking, and performance in standardized tests (Cresswell & Speelman, 2020). Despite its importance, many individuals, particularly students,

struggle with mental arithmetic due to a lack of engaging and structured practice methods.

The increasing reliance on digital tools for calculations has diminished opportunities for individuals to develop mental math skills, leading to a cycle of dependency on external aids (Vinney, 2024). This dependency not only weakens numerical reasoning but also stifles motivation and confidence in tackling mathematical challenges. To address this gap, the Mental Math Mobile Application was developed, offering an interactive and structured platform for users to enhance their arithmetic abilities through training, practice, and competition.

The application is designed to cater to a diverse audience, including students, educators, and individuals seeking to improve their numerical fluency. It features a Training Module that teaches arithmetic techniques, an Interactive Practice Module with adaptive difficulty levels, and a Ranking Competition Module that fosters motivation through gamification (StudyPug, 2018). By integrating education with technology, the app aims to make mental math practice more accessible, effective, and engaging, ultimately promoting lifelong numerical proficiency.

The development of this application followed the Incremental Development Model, ensuring a systematic approach to requirements analysis, design, testing, and implementation (GeeksforGeeks, 2018). Key functionalities were validated through usability testing, which confirmed the app's effectiveness in improving users' mental arithmetic skills and overall engagement.

This document outlines the design, implementation, and testing of the Mental Math Mobile Application, highlighting its strengths, areas for improvement, and potential for future enhancements. By bridging the gap between traditional learning methods and modern technology, the app serves as a valuable tool for fostering numerical confidence and competence in users of all ages.

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LITERATURE REVIEW

Mental arithmetic skills play a fundamental role in cognitive development and daily life applications, yet many learners struggle due to inadequate practice methods. Recent studies have demonstrated that regular mental math practice enhances numerical fluency, logical reasoning, and academic performance (Cresswell & Speelman, 2020). However, the increasing reliance on digital calculators has created a dependency that undermines these cognitive benefits (Vinney, 2024). This challenge has prompted the development of various mobile applications designed to improve mental arithmetic abilities through interactive training and gamification.

Several prominent applications have emerged in this domain, each employing distinct approaches to mental math training. Math Brain Booster Games offers a comprehensive suite of features including daily challenges, adaptive difficulty levels, and detailed progress tracking. While its rich functionality promotes engagement, the interface complexity may present usability challenges for certain user groups. In contrast, Mental Math - Math Trainer adopts a minimalist design focused exclusively on arithmetic drills, sacrificing motivational elements for simplicity. Cool Math Games Learning Game strikes a balance between education and entertainment through visual gamification, though it lacks structured learning pathways and competitive features that could enhance long-term retention.

The current landscape of mental math applications reveals a notable gap between engagement and educational structure. Many applications either prioritize gamification at the expense of systematic learning or focus too narrowly on drills without incorporating motivational psychology. This observation informed the development of the Mental Math Mobile Application, which synthesizes the most effective elements from existing solutions while addressing their limitations. The application's three-tiered approach - combining structured training, adaptive practice, and competitive elements - represents an innovative attempt to optimize both learning outcomes and user engagement.

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The Training Module employs animated tutorials and interactive examples to build fundamental arithmetic skills, addressing the need for conceptual understanding often overlooked in drill-based applications. The Practice Module implements an adaptive algorithm that adjusts difficulty based on user performance, providing personalized challenges while maintaining an appropriate level of difficulty. Perhaps most innovatively, the Competition Module introduces timed challenges and leaderboards, leveraging gamification principles to sustain motivation (StudyPug, 2018). This multi-faceted design not only accommodates diverse learning styles but also creates a more immersive and rewarding practice environment.

User experience considerations have been central to the application's design philosophy. The interface maintains clarity and intuitiveness while supporting the complex functionality required for effective mental math training. Special attention has been given to visual hierarchy, feedback mechanisms, and progression systems to ensure accessibility across age groups and skill levels. By integrating pedagogical best practices with engaging game mechanics, the application aims to transform mental math practice from a tedious chore into an enjoyable habit, potentially fostering long-term numerical proficiency.

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METHODOLOGY

The development of the Mental Math Mobile Application follows an incremental model to ensure continuous refinement and alignment with user needs. This chapter outlines the core requirements, system design, and implementation strategies adopted throughout each development phase.

To identify the specific needs and expectations of users for the Mental Math Mobile Application, a comprehensive user requirements analysis was conducted through digital surveys using Google Forms. The target respondents included students, educators, and individuals interested in improving mental arithmetic skills. The survey focused on user preferences for interface design, key functions, and desired learning approaches. Feedback gathered from this process was used to outline the functional requirements of the application.

The data revealed the need for several core features. First, a user registration system was established to manage access and personalize experiences, with users beginning at Level 1 upon sign-up. A Training Module was proposed to provide categorized, interactive instruction in addition, subtraction, multiplication, and division. This was followed by a Practice Module designed with progressive difficulty levels and a performance tracking system that records accuracy and response time. The Competition Module was also introduced to foster motivation by ranking participants weekly and offering real-time feedback through a leaderboard system. Finally, a User Profile Management feature was implemented to support user engagement through error logs, weekly reports, and visual badges that reward progress. Optional settings such as night mode and sound preferences were included to enhance usability.

In addition to user surveys, a comparative analysis of existing mental math applications such as Math Brain Booster and Mental Math Trainer was conducted. This analysis helped refine the application structure by integrating gamification, structured training, and visual feedback mechanisms to ensure both educational value and user engagement. The features selected aimed to balance pedagogical depth with interactive enjoyment to support a wide range of learners.

In addition to functional requirements, several non-functional aspects were prioritized to support usability and long-term performance. The application is developed using a scalable, cloud-based architecture (Firebase) that ensures real-time synchronization of data and accommodates multiple concurrent users. Training and practice modules are accessible offline, with data automatically synced upon reconnection to support users in low-bandwidth environments. The system is designed for responsiveness, offering instant feedback and fast interface loading. Security is enforced through encrypted data transmission and password protection. Modular development allows independent maintenance and updates of system components, while automated backups ensure data integrity and simplify future improvements. These combined requirements contribute to a robust, responsive, and user-centered educational application.

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The development of the Mental Math Mobile Application followed an incremental development methodology, chosen for its adaptability to evolving user needs while ensuring systematic quality control. This structured approach comprised four key phases—requirements analysis, design and development, testing, and implementation—each contributing to the application's educational effectiveness and technical reliability.

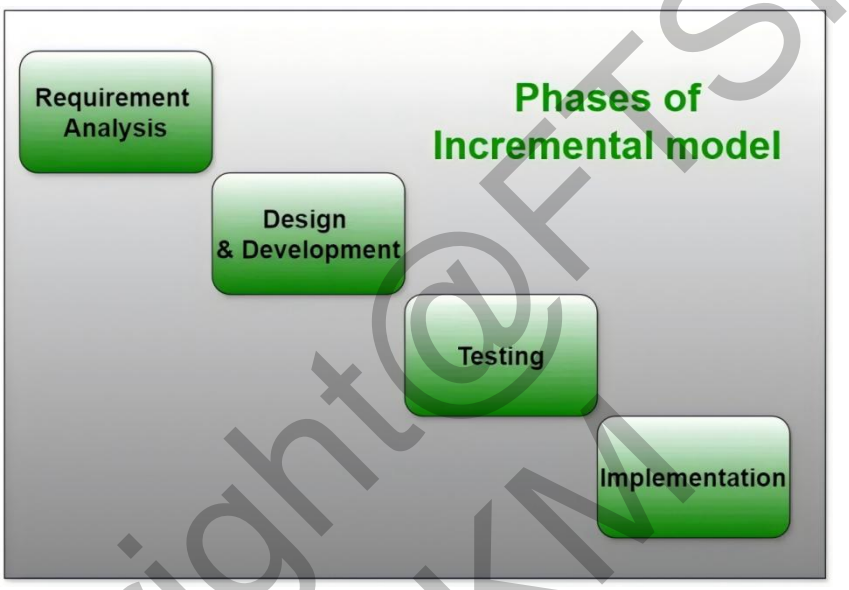

Figure 1 Increment Development Model (GeeksforGeeks, 2018)

The initial phase involved comprehensive requirements gathering through surveys and consultations with students, educators, and mathematics experts. The analysis identified three primary functional needs: a structured training module to teach arithmetic techniques, adaptive practice exercises with progressive difficulty levels, and a competitive ranking system to enhance user motivation. These requirements were further validated by benchmarking existing mental math applications, which revealed notable shortcomings in user engagement, content modularity, and pedagogical scaffolding.

The system architecture was designed with a three-tiered framework, balancing user experience with technical performance. The presentation layer utilized Material Design principles to ensure a clean, intuitive interface, while the application layer

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featured modular components responsible for functionalities such as real-time progress tracking and dynamic question generation. The data layer, built on Firebase Realtime Database, enabled seamless synchronization of user data across sessions and devices. Key innovations included a finite-state machine to manage training module flow and an optimized algorithm for leaderboard computation that balanced accuracy with response speed. Development proceeded iteratively, allowing for feature refinement and user feedback integration throughout the process.

To ensure both functionality and educational value, rigorous testing procedures were employed. Technical verification encompassed unit testing, integration testing, and compatibility checks across multiple Android devices. Usability testing with target users focused on interface intuitiveness, error tolerance, and task efficiency. Results indicated significant improvements in completion time and user satisfaction compared to pre-development benchmarks. These findings validated the application's potential to support effective mental math learning through an accessible mobile platform.

Deployment was executed using a phased rollout strategy, enabling real-world performance monitoring and incremental feature expansion. A feedback-driven update system was integrated to facilitate continuous improvement, while backend analytics tools were employed to track stability, engagement, and feature usage. Post-deployment data revealed high user retention rates and sustained interaction across modules, underscoring the application's success in maintaining learner motivation—a critical factor in educational technology adoption.

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RESULTS

The implementation section covers how essential features were realized in code, highlighting the logic and structure behind key functionalities such as user registration, level-based question generation, real-time progress tracking, and leaderboard integration. The development of major user interface components is also described, with emphasis on ensuring seamless and intuitive user interactions. Special attention is given to the integration of Firebase Authentication and Realtime Database, which

enables real-time data synchronization, user management, and persistent performance tracking.

The application defines five levels (Lv.1 to Lv.5), each linked to a set of problems stored in Firebase. At Lv.1, users encounter only addition problems. Lv.2 introduces subtraction and basic mixed problems. Lv.3 incorporates multiplication, while Lv.4 offers questions covering all four arithmetic operations. At Lv.5, the system prioritizes more complex, mixed-type problems that require deeper mastery.

When the user begins a session, the application presents a timed quiz interface (Figure 3) containing a countdown timer, the question prompt, an input field, and a submission button. Users are required to compute answers mentally and round decimal results to a maximum of two decimal places following standard rounding rules. Upon submission, the system evaluates the response and provides immediate feedback. After answering three questions correctly in succession, the user advances to the next level.

The module also includes a time-management feature to promote quick thinking. If a user fails to submit an answer within one minute, a dialog appears offering options to retry the question or exit to the main menu. Upon reaching Lv.5 and completing the progress bar, users unlock access to the Competition module, where they can engage in more challenging exercises and compare their performance with others.

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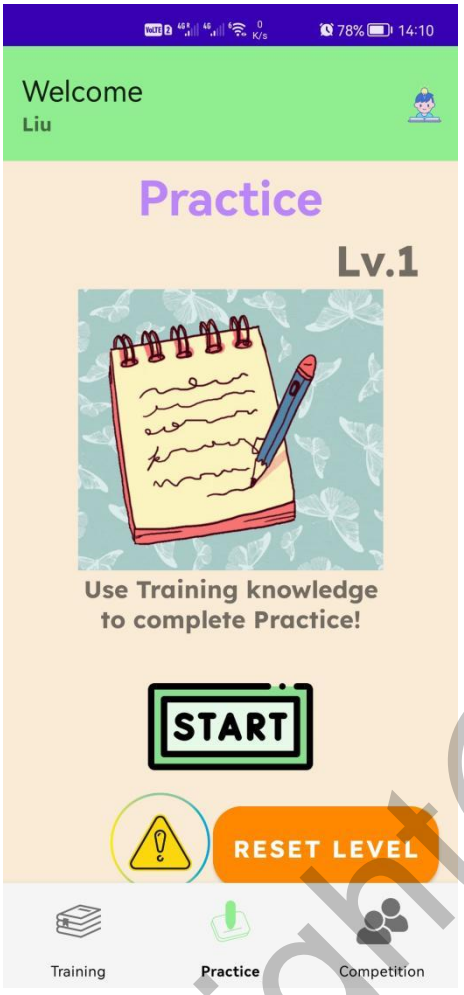

Figure 2 Practice Fragment

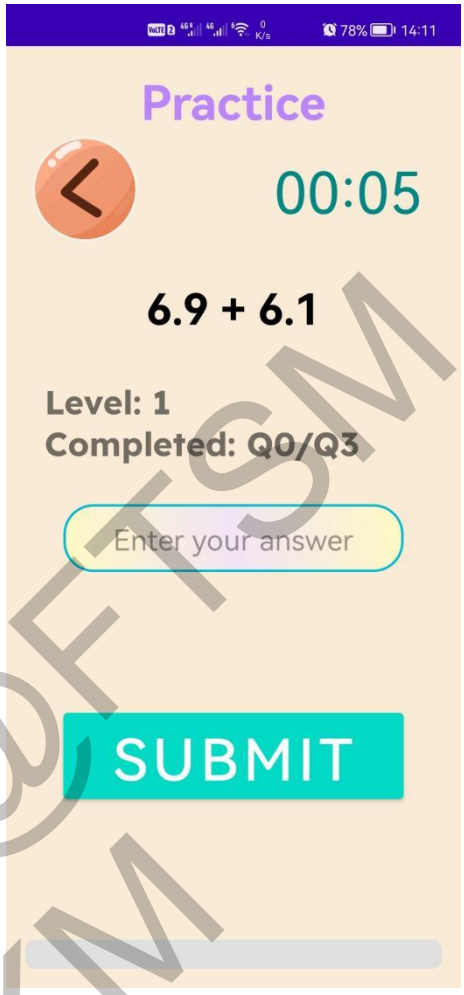

Figure 3 Practice Question

This module features a weekly quiz and a real-time leaderboard system. As illustrated in Figure 4, the leaderboard ranks users based on their accuracy. In cases of equal accuracy rates, completion time serves as a secondary ranking factor. If a user has already participated, their position is highlighted on the leaderboard.

Unlike the Practice module, users proceed using a Next button, which saves each response and transitions to the next question. Unanswered questions are automatically marked as incorrect and cannot be revisited. The quiz supports mid-session pauses. If users leave before completion, the Start button changes to Continue, showing the remaining time. This allows them to resume where they left off, provided it is within the one-hour limit.

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Figure 4 Week3 Leaderboard

After completing the quiz, users are redirected to the result page, which summarizes accuracy, total time used, and detailed performance per question. Each item can be expanded to show the question, the user's answer, the correct answer, and time taken—helping users review and reflect on their performance.

Upon submission, the leaderboard is automatically updated with the user's new result (Figure 4.5 a–b), allowing participants to track their rank in real time and stay motivated through weekly challenges.

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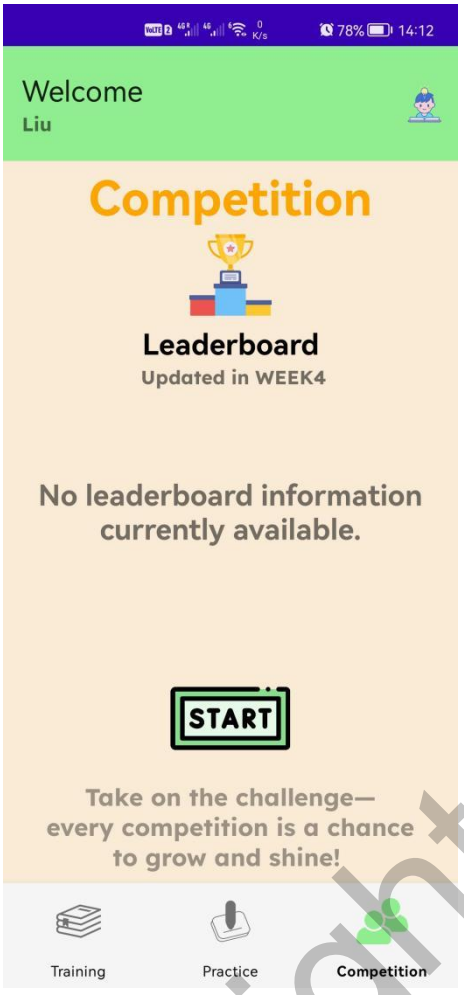

Figure 5 (a) Competition Nodata

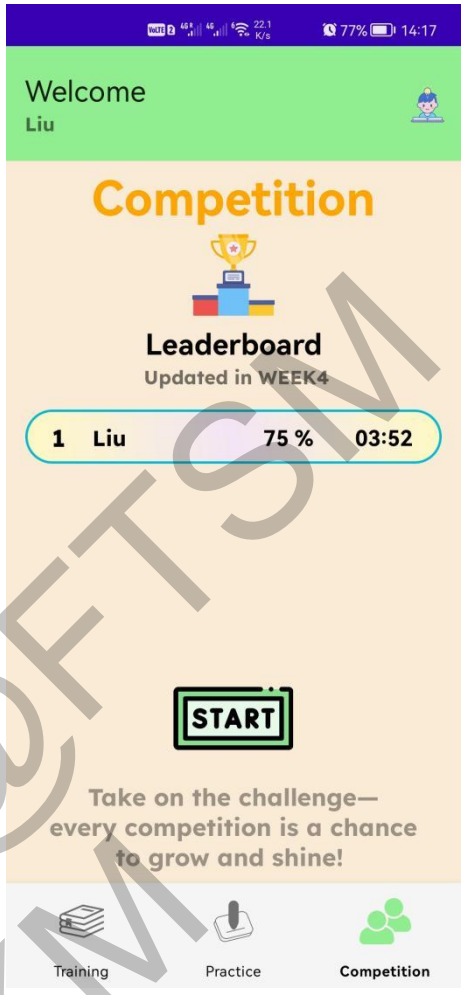

Figure 5 (b) Competition Week4 Updated

The evaluation process ensures that all core features of the Mental Math Mobile Application—including training modules, practice sessions, competition functions, and progress tracking—operate as intended. Functional and usability testing were conducted with student participants to verify the app's reliability, responsiveness, and alignment with user expectations.

Functional testing was carried out to ensure that every feature works according to the specifications. The following functionalities were tested:

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Table 1 Use Case Testing for Account Registration

Test Case ID	TC-01			
Function ID	FN-01			
Objective	To ensure the account registration is valid and successful			
No.	Input	Expected Result	Requirement	Procedure
1	Enter email	No error	Required for registration	None
2	Enter username	No error	Required for registration	None
3	Enter password	No error	Required for registration	None
4	Enter repassword	No error	Required for registration	None
5	Click "Register"	Redirect to login page	Valid input provided	TC-02

Table 2 Use Case Testing for User Login

Test Case ID	TC-02			
Function ID	FN-02			
Objective	To ensure login works with correct credentials			
No.	Input	Expected Result	Requirement	Procedure
1	Enter valid email	No error	Email exists	None
2	Enter valid password	No error	Password correct	None
3	Click "Login"	Redirect to home page	Credentials correct	TC-03

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Table 3 Use Case Testing for Training Completion Status

Test Case ID	TC-03			
Function ID	FN-03			
Objective	To ensure training module updates completion status and marks as done (" √ ")			
No.	Input	Expected Result	Requirement	Procedure
1	Complete one of training submodules	Status change to "done"	Training module selected	None
2	Exit before completion	No error	User exits mid-training	None
3	Re-open completed mocule	Status remains "done"	Previously marked	None

Table 4 Use Case Testing for Practice Question Generation

Test Case ID	TC-04			
Function ID	FN-04			
Objective	To ensure practice questions match user level appropriately			
No.	Input	Expected Result	Requirement	Procedure
1	User level = 1	Only addition questions generated	The default user level is lv1	Auto load questions
2	User level = 2	Addition, subtraction questions shown	User upgrades to lv2	Adjusted the path to get Firebase questions
3	User level = 3	Addition, subtraction, multiplication questions shown	User upgrades to lv3	Adjusted the path
4	User level = 4	Questions from all operations and mixed, equal ratio (20% each)	User upgrades to lv4	Adjusted the path

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5	User level = 5	Increase the probability of generating multiplication, division and mixed	User upgrades to lv5	Adjusted the path

Table 5 Use Case Testing for Practice Progress and Level Up

Test Case ID	TC-05			
Function ID	FN-05			
Objective	To ensure progress tracking and auto-upgrade on correct answers			
No.	Input	Expected Result	Requirement	Procedure
1	Correct answer submitted	Progress + 1	Progress < 3	Update in Firebase
2	3 correct answer in row	Level + 1	User not reached Max level (lv5)	Reset progress to 0
3	Wrong answer	Progress reset to 0	Any level	Reset progress to 0
4	Answer over 60 seconds	Time limit	User did not answer in 60 seconds	Display a dialog

Table 6 Use Case Testing for Competition Quiz & Week

Test Case ID	TC-06			
Function ID	FN-06			
Objective	To ensure competition module updates week and fetches correct quiz			
No.	Input	Expected Result	Requirement	Procedure

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1	Click "Start"	Record the start time	No ongoing competition	Update in Firebase
2	Click button to Submit	Save current answer and display next question	There are unfinished questions	Save to temporary records
3	Click button to Submit	Calculate the results and report	All questions finished	Remove temporary records
4	Exit midway	Partial progress saved	No more than an hour from the start	Provide resume for users (No.6)
5	Answer over 60 minutes	Time limit	User did not finish in 60 minutes	Calculate and default incomplete questions as errors
6	Continue unfinished competition	Resume and show incomplete questions	No more than an hour from the start	Load from temporary records

Table 7 Use Case Testing for Leaderboard

Test Case ID	TC-07			
Function ID	FN-07			
Objective	To ensure leaderboard correctly displays all users' competition scores and rankings			
No.	Input	Expected Result	Requirement	Procedure
1	User redirect to Competition page	Load current leaderboard	Any user participated in this week's Competition	Sorted display
2	User A score > User B	User A ranks higher	Sorted by score > time	Logic applies
3	Two user same score	Rank by time	Lower time ranks higher	Tie-breaker
4	No user data	Leaderboard shows Tip	No user participated in this week's Competition	None

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Usability testing is a crucial process to assess whether the developed Mental Math Mobile Application meets users' expectations in terms of functionality, interface clarity, ease of navigation, and overall satisfaction. This phase ensures that the core objectives of the application—enhancing mental arithmetic skills through structured and engaging modules—are effectively delivered to the target audience before real-world deployment.

To collect usability data, a Google Form was distributed along with the application APK file and a user manual. This allowed users to freely explore the app's modules, including training, practice, and competition features, and then provide feedback on various usability aspects. The questionnaire employed a five-point Likert scale: 1 – Strongly Disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, 5 – Strongly Agree. Table 8 shows the interpretation scale table of the mean score (Jamil, 2002).

Table 8 Mean Interpretation Scale

Mean Score	Interpretation
1.00 - 2.32	Low
2.33 - 3.65	Medium
3.66 - 5.00	High

A total of 10 students participated in the testing. The questionnaire included 12 items across different aspects of the application. Table 9 below summarizes the findings:

Table 9 Usability Testing Results

No.	**Items**	**Mean**
1	The app is easy to navigate.	4.20
2	The interface design is clear and attractive.	4.30
3	The training module helps me understand arithmetic techniques.	4.00
4	The practice module is suitable for my current math level.	4.10
5	The content difficulty increases in a manageable way.	4.10

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6	I like the real-time feedback and progress tracking.	4. 60
7	The leaderboard motivates me to practice more.	4. 50
8	How do you feel about the feature to resume an unfinished competition quiz?	3. 90
9	The time limit for the practice and competition modules of this application is reasonable.	4. 10
10	The app responds quickly and works smoothly.	4. 50
11	The application worked normally during its usage and no abnormal situations occurred.	4. 50
12	Overall, I am satisfied with the app.	4. 30

The usability testing results indicate a high level of user satisfaction, particularly with features like real-time feedback, leaderboard motivation, and system responsiveness. All items scored above 3.66, with most exceeding 4.20. While the ability to resume an unfinished quiz scored slightly lower (3.90), it still falls within the "high" interpretation range, suggesting room for future UI enhancement.

This feedback has been instrumental in supporting a comprehensive evaluation of the application's usability and has provided valuable insights for continuous improvement. Updates based on user suggestions—such as better font adaptability and content scaling—are being considered for future versions to further improve the user experience.

CONCLUSION

The Mental Math Mobile Application developed in this study successfully provides an engaging, structured, and user-friendly platform for enhancing arithmetic proficiency. Through the integration of three core modules — Training, Interactive Practice, and Ranking Competition—the application allows users to learn and practice at their own pace while being motivated by real-time feedback and leaderboard rankings. The ability to track user progress across sessions and dynamically generate questions based on user levels makes the app both educationally effective and technically reliable.

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This application has also demonstrated strong potential for further scalability and adaptation across different educational environments. Features such as real-time data synchronization, cloud-based progress storage, and interactive performance feedback enhance its suitability for both individual and classroom use. The incorporation of adaptive difficulty levels and responsive design principles ensures that learners remain engaged throughout the process of mental arithmetic training.

However, several areas for improvement were identified. These include the addition of multilingual support, more diverse question types, and customizable interface settings to better serve users with varying needs and preferences. Enhancing these aspects will contribute to making the application more inclusive and pedagogically robust.

The Mental Math Mobile Application developed through this project serves as a model for how mobile technology can support effective and enjoyable numeracy learning. With future updates, including content enrichment and user-driven enhancements, this application is well-positioned to support long-term learning goals and sustain user engagement. The use of structured modules, competitive elements, and personalized feedback makes it an attractive solution for improving mental math skills in both formal and informal learning contexts.

Overall, the design and development of this application have met the intended educational objectives. The project not only delivers a functional digital learning tool but also contributes to the growing body of research on mobile-based mathematics education. It is expected that, with continuous refinement, the Mental Math Mobile Application will play a meaningful role in improving arithmetic literacy and fostering learner confidence in mathematical thinking.

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