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Research Article

Mobile Game Development on Mathematical Subject for Primary School Children

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ABSTRACT

Mathematics can be challenging for many children, particularly in grasping basic concepts like addition, subtraction, and number recognition, which can hinder their confidence and academic progress. Traditional teaching methods often feel tedious for preschoolers, who benefit more from interactive and playful learning experiences. This study focuses on developing a gamified educational tool to enhance preschoolers' math abilities by combining engaging game elements, like rewards and challenges, with foundational educational content. By integrating principles such as repetition and scaffolding, the tool aims to make math practice enjoyable, improve cognitive development, and foster a positive attitude toward math, ultimately supporting future academic success.

Keywords: Mathematics Skill, Educational Game, User Interface, Preschoolers, Speech Recognition, Gamification

INTRODUCTION

In today's world, games have become an essential and influential part of children's lives, often starting at a very young age [1]. With the rapid advancement of technology, children are increasingly immersed in the digital realm, which has become a fundamental component of their everyday routines [2]. Many children spend a significant portion of their time engaging with digital games, which not only entertain but also shape their social, cognitive, and emotional development. Studies have demonstrated that gaming can influence children's social competence, tracking this impact from as early as age six and continuing through their developmental stages at ages eight, ten, and twelve [3]. The role of games in childhood extends far beyond mere entertainment; they serve as powerful tools that promote creativity, enhance critical thinking skills, and foster a sense of independence [4]. In academic discussions, it is widely accepted that play and games are vital for preparing children both physically and cognitively for the demands of life. These interactive experiences help children practice problem-solving, decision-making, and other essential life skills in a safe and engaging environment [5], [6], [7].

Furthermore, children are naturally driven by fun and enjoyable learning experiences, which have been shown to increase their academic success, engagement, and commitment to the learning process. When learning is enjoyable, children are more likely to remain motivated, which leads to more effective and lasting educational outcomes [8]. On the contrary, when enjoyment is diminished, their enthusiasm and willingness to engage with the subject can decrease, leading to a reduction in learning efficiency. For example, in the realm of educational games, it is crucial that these tools remain motivating, exciting, and enjoyable in order to maintain children's interest and enhance their learning potential.

Mathematics, however, continues to be one of the most dreaded and least popular subjects for many children [9]. The abstract nature of math, coupled with the challenge of mastering and applying concepts such as addition, subtraction, multiplication, and division, often requires strong visual and cognitive skills. Despite this, there remains a global deficiency in providing effective educational tools and resources that help children develop these critical math skills. Many children struggle to grasp basic mathematical concepts due to the lack of engaging, interactive, and supportive learning environments. Educational gaming tools offer a promising solution by allowing children to

practice math in a fun, low-pressure environment. These tools reduce the fear of making mistakes, as children can explore and learn without the fear of embarrassment, thereby building their confidence and proficiency in math [4][10][11].

In addition to transforming the way children approach math, recent technological advancements have had a broad influence on various aspects of life, including education [12]. The widespread use of smartphones and other digital devices has revolutionized how children learn by providing innovative and engaging ways to interact with educational content [12], [13]. Smartphones, in particular, have made learning more accessible, offering interactive and flexible opportunities for children to study at any time and place. This has eliminated the need for traditional face-to-face lessons with teachers, as children can now engage with educational materials independently through apps and games play [13], [14], [15], [16]. Video games, which are widely popular among children of all ages, are easily accessible on smartphones and other gaming devices at home, providing children with ample opportunities to learn through [17], [18], [19]

The focus of this research is to develop a mathematical education game specifically designed for children aged 6 to 10, targeting foundational math skills such as addition and subtraction. The game will combine traditional numerical elements with modern technological features like speech recognition to create an engaging and interactive learning experience. This approach aims to make math both enjoyable and educational, helping children overcome their fear of the subject while reinforcing their understanding of key mathematical concepts. By integrating game-based learning with speech recognition, the game will provide real-time feedback and allow children to actively participate in their learning process, ultimately enhancing their math skills in a fun and motivating way [19].

RELATED WORK

Games are often integrated into mathematics lessons, particularly at the primary school level [20]. Various games have been developed to teach math, including one example called the Arithmetic game, which is accessible on both desktop and Android platforms. This paper introduces a game that uses a method to dynamically and automatically adjust difficulty levels based on the characteristics of both the game and the educational content. Experiments have shown that the game received positive feedback for its user interface, system performance, and educational value. As a result, we conclude that the game is enjoyable and easy for children to use. Furthermore, playing this game helps children enhance their calculation speed and accuracy in arithmetic. The game effectively blends entertainment with education and includes multiple challenging levels for children, although it does not specify any server requirements [21].

Another game is EduBingo, these concepts are randomly selected from a database, resulting in mostly unique cards for each student, especially regarding the arrangement of concepts and numbers. The lecturer, serving as the game host, poses statistical questions that correspond to the concepts and numbers on the cards. Like in traditional Bingo, students mark the appropriate spaces, with the goal of being the first to complete a full row or column. The first student to do so shouts "Bingo!" and the lecturer checks the accuracy of the winning card. To enhance the learning experience, the lecturer then discusses the questions and solutions with the students. This game operates in a one-on-one digital classroom environment where each student uses a device such as a tablet, handheld device, or electronic dictionary, all with wireless capabilities[22].

Additionally, another game utilizes a serious gaming approach, consisting of three segments designed to promote knowledge acquisition and skill development in a fun, desire-driven learning environment. The first segment, known as the Numbers game, focuses on calculation activities, including identifying integers, determining multiples, finding divisors, and calculating and simplifying the sum of two decimals. In this segment, the player answers questions by maneuvering the main object toward circles with correct answers while avoiding incorrect ones. This game does not specify a platform [23]

METHODS AND METHODOLOGY

Throughout each phase of the ADDIE model, collaboration among designers, developers, educators, and parents is crucial to ensure the educational game aligns with its goals, technological capabilities, and user expectations. In the analysis phase, a comprehensive approach is employed to understand the needs of children aged 6 to 10, along with their learning objectives. This involves employing various analysis methods, such as surveys, interviews, and focus groups with children, parents, and educators, to gather insights into children's learning patterns, math abilities, interaction preferences, and adaptability to technology. Additionally, observation studies of how children engage with

educational tools can offer valuable data on user behaviors. Parental involvement is also assessed, examining their willingness to engage with the game and support their child's learning. Competitive analysis of existing educational games, using techniques like SWOT analysis (strengths, weaknesses, opportunities, and threats), helps identify market demands, trends, and areas for improvement.

In the design phase, the structure, content, and user interface of the game are planned to be simple, vibrant, and engaging for young users. Wireframes and prototypes are developed and tested with user feedback to ensure the interface and experience are optimized for children. During the development phase, the coding and software creation occur, integrating features like speech recognition, while conducting rigorous usability testing to ensure functionality and ease of use.

The implementation phase focuses on the game's launch, starting with iOS devices, accompanied by a smooth sign-up process and marketing strategies designed through target audience segmentation and digital analytics. Finally, in the evaluation phase, the game's impact on children's learning is assessed using a combination of quantitative methods likes performance tracking, pre- and post-test assessments and qualitative methods such as user feedback, interviews to gather continuous feedback, making iterative improvements to maintain its educational effectiveness and user engagement shows in Figure 1 below.

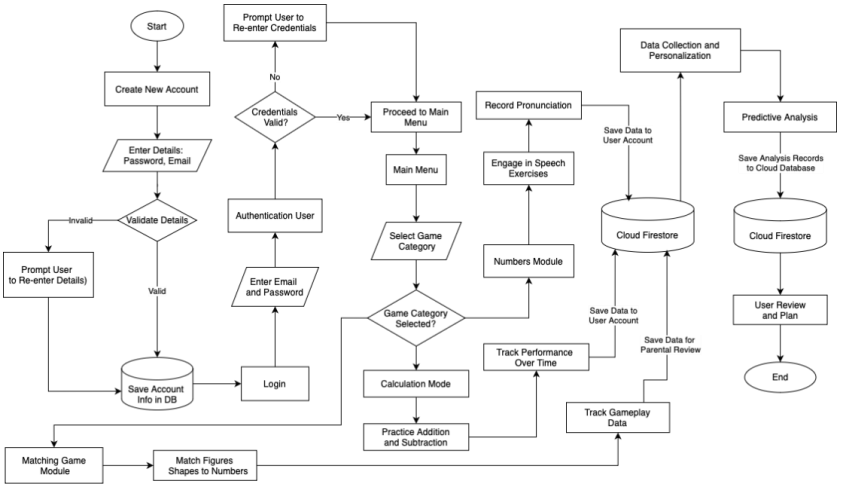


Figure 1: System Process Flowchart

The system architecture is intricately designed around a mobile application that functions as the primary interface for delivering mathematical education to children. This architecture effectively utilizes two key data sources: cloud storage, which centralizes user data and facilitates seamless cross-device synchronization, and local device storage, which allows for user-uploaded datasets that can enhance the personalized learning experience. By employing cloud storage, the application ensures that user progress, achievements, and preferences are consistently accessible across multiple devices, enabling children to continue their educational journey without interruption, regardless of whether they switch from a tablet to a smartphone.

The mobile game is composed of a rich variety of educational modules aimed at making learning mathematics enjoyable and engaging. For instance, the speech-recognition-enabled number pronunciation feature is designed to help children accurately articulate numbers, thereby enhancing their verbal and auditory skills alongside their mathematical understanding. This interactive element not only aids in learning but also encourages active participation, as children can hear and practice the correct pronunciation of numbers in real time.

In addition to pronunciation, the application includes interactive matching games that promote counting and pattern recognition, crucial skills for building a solid mathematical foundation. These games are designed to capture the attention of young learners, encouraging them to think critically and solve problems while having fun. The educational modules also feature engaging calculation exercises focused on addition and subtraction, allowing children to practice these essential arithmetic skills in a playful, low-pressure environment. This approach helps to alleviate anxiety often associated with math and fosters a sense of achievement as children complete tasks and progress through levels.

To facilitate smooth communication and real-time data processing between the mobile application and cloud services, a dedicated cloud function service is integrated into the system architecture. This service is vital for maintaining the application's responsiveness, allowing for dynamic content updates and ensuring that users receive the latest educational materials and feedback instantly. For example, as children progress through different levels or complete specific challenges, the cloud service can update their profiles, adjust the difficulty of future tasks, and provide instant feedback, thereby enhancing the overall learning experience.

Overall, this system architecture show in Figure 2, offers a robust, user-friendly, and dynamic learning platform specifically designed for children aged 6 to 10. By integrating advanced technology with effective pedagogical strategies, the application not only promotes engagement and enjoyment in learning mathematics but also provides a comprehensive educational experience. This innovative approach aims to foster a lifelong love of learning while equipping young learners with the foundational math skills they need for future academic success.

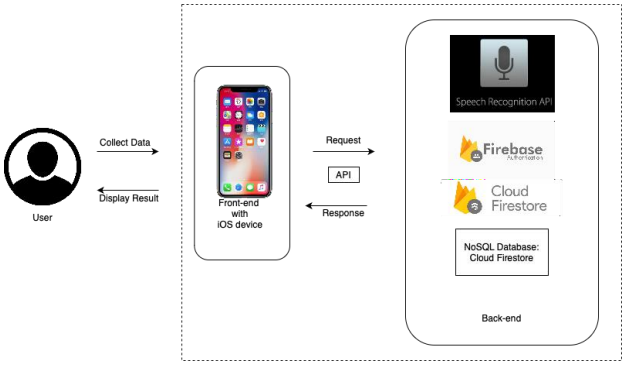


Figure 2: The architecture of mobile game

3.1 Test Plan

Four test plans have been established for each component to ensure the developed mobile game works properly.

Unit Testing: Unit testing in this game will focus on testing individual units of code, such as methods and functions, to ensure they perform as expected. Each module, like Sign up, Select Game Categories, and Calculation Mode, will undergo unit testing to validate their functionality. Unit tests will be conducted using testing frameworks like Jest or Mocha to automate the testing process and ensure reliability. The advantage of unit testing is the ability to quickly identify and fix bugs within specific code units without the need to build the entire application.

Integration Testing: Integration testing in this mobile game will involve combining multiple modules and functionalities to test their interactions. For example, integration testing will verify that the Sign Up module correctly interacts with the Select Game Categories module and that user progress is accurately tracked across different game modes. Testing the integration of speech recognition in the Numbers module will ensure seamless functionality. Integration testing will be performed using tools like Selenium or Cypress to simulate user interactions and validate system behaviour.

Usability Testing: Usability testing in the game will focus on evaluating the application's user experience, particularly for children aged 6 to 10. Real users within the target age group will interact with the application, providing feedback on its usability, intuitiveness, and engagement. Observations and feedback will be collected to identify any areas of confusion or improvement opportunities. Usability testing will be an iterative process, with feedback used to refine the interface and enhance the overall user experience.

Acceptance Testing: Acceptance testing in the game will involve assessing the application against predefined acceptance criteria to determine if it meets user requirements and expectations. The entire application, including all modules and functionalities, will be tested by users to ensure it aligns with the project objectives. Any modification requests from users will be promptly addressed to enhance user satisfaction. Once acceptance criteria are met and users are satisfied with the application's functionality and usability, this game will be accepted and ready for delivery.

By employing a detailed testing strategy that covers unit testing, integration testing, usability testing, and acceptance testing, this mobile game seeks to ensure its reliability and usability, while also providing a satisfying user experience. The ultimate goal is to transform the way children view and engage with mathematics.

3.2 Develop application

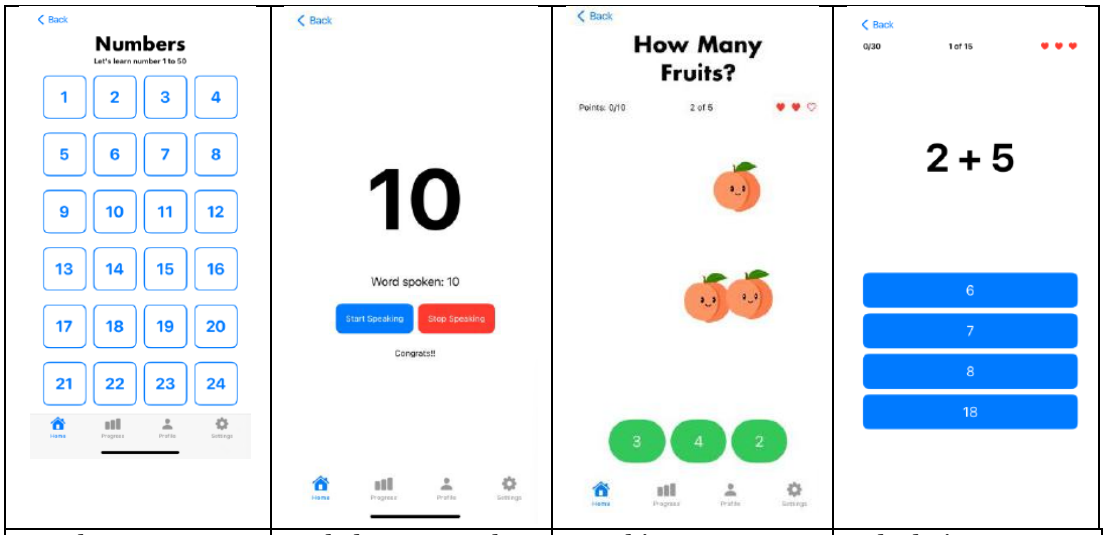
The MathMania application starts with users creating a new account, where they provide essential details for authentication and progress tracking. The Sign-Up page, as illustrated in Figure 3 and Main Menu in Figure 4, guides users through this initial setup process. Once logged in, users can choose from a variety of engaging game categories, including Numbers module, Matching Game, and Calculation Mode, each designed to enhance mathematical understanding in an enjoyable manner.

Figure 3: Sign Up Page

Figure 4: Main Menu

In the Numbers module, children participate in interactive speech recognition exercises that help them practice number pronunciation. This not only aids in their verbal skills but also tracks their progress, saving valuable data to their account for future reference. The Matching Game encourages players to match figures or shapes with corresponding numbers, making it a fun and educational way to enhance recognition skills. The gameplay data from this module is stored in a database, allowing parents to review their child's engagement and progress. Meanwhile, the Calculation Mode provides a platform for children to practice essential addition and subtraction skills, tracking their performance over time to monitor improvements.

After selecting a game category, users actively engage with the chosen module through a series of gameplay activities showed in Figure 5. For example, in the Numbers module, children verbally express numbers, while in the Matching Game, they tap or match figures. The application is designed to keep children motivated and engaged through gamified elements, such as rewards and progress tracking. These features foster a positive learning environment that encourages children to explore math in a playful context.



Numbers Screen	Verbal game number	Matching game screen	Calculation game screen

Figure 5: a) Numbers Module, b) Verbal game in Numbers Module , c) Matching game screen d)Calculation game screen

As children advance through the game and complete various activities, the application employs machine learning algorithms to analyze their performance data. This analysis involves identifying patterns in user behavior, assessing areas of strength and areas needing improvement, and generating personalized recommendations for further learning. For instance, if a child excels in the Calculation Mode, the app might suggest additional exercises tailored to reinforce specific mathematical concepts, or it could provide new challenges to further enhance their skills.

In addition to personalized learning paths, MathMania includes a predictive analysis functionality that allows users to forecast future performance based on input parameters such as immersion time and gameplay duration. By utilizing algorithms like random forest regression, the application can predict user performance and calculate potential outcomes, offering insights that help users strategize their learning journeys. This predictive feature empowers children and parents alike to make informed decisions about their educational activities, enhancing overall engagement and progression.

Finally, the application allows users to save their analysis records to a secure cloud database, ensuring easy access and reference. This feature enables children and their parents to track progress over time, review past performance, and monitor their learning trajectories. By integrating advanced data analysis techniques with user-friendly features, MathMania delivers a comprehensive and interactive mathematical education experience tailored specifically to children aged 6 to 10. This innovative approach not only fosters enthusiasm and confidence in learning math but also cultivates a deeper understanding of mathematical concepts, laying a solid foundation for future academic success.

RESULT AND DISCUSSIONS

This mobile education game effectively fulfills the research requirements by implementing robust user management features, including Sign Up and Sign In functionalities. These features not only ensure secure access for users but also allow parents to actively track their child's progress and engagement with the application. The app is thoughtfully designed with three distinct categories: Numbers module, Matching Game, and Calculation, catering to the diverse learning preferences and skill levels of children aged 6 to 10. Each category is crafted to provide a unique learning experience, ensuring that children can choose the module that best suits their individual needs.

One of the standout features of the application is its incorporation of innovative technologies, such as speech recognition, particularly in the Numbers category. This technology fosters interactive learning by allowing children to verbally express numbers, which significantly enhances their engagement and helps them develop both verbal and mathematical skills simultaneously. The system is adept at tracking user progress and performance, providing parents with valuable insights into their child's improvements over time. This transparency helps parents understand their child's learning journey and encourages further involvement in their education.

Despite its many successes, the mathematic mobile game does have limitations, particularly its reliance on specific file formats for input. This could potentially restrict the app's flexibility and adaptability to different educational content or user needs, highlighting an area that may benefit from future updates or enhancements. Addressing this limitation could significantly broaden the scope and functionality of the application, allowing it to better meet the varied requirements of its users.

Overall, this game offers an engaging and effective platform for math learning, successfully aligning with educational goals while making the process enjoyable for children. As illustrated in Figure 6 below, a remarkable 94.4% of parents express a desire to combine math learning with their children's education, indicating a strong demand for tools that support integrated learning approaches. This overwhelming interest further underscores the game's relevance and potential impact in the field of early childhood mathematics education.

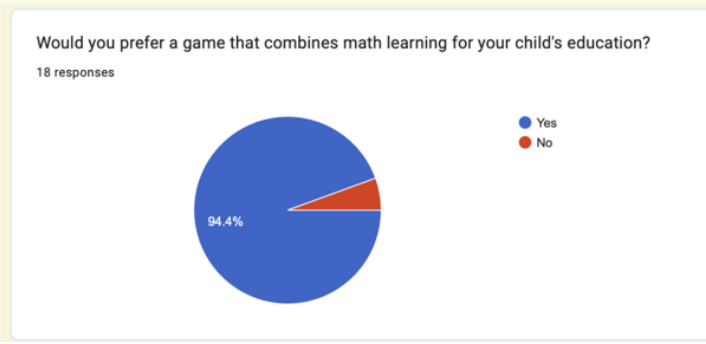


Figure 6: The percentage of parents who support a game that merges enjoyment game with mathematics education.

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