

Development and Evaluation of a Math Game Application for Toddlers: Enhancing Early Mathematical Skills through Digital Play

Alma Christie C. Reyna¹

¹College of Engineering and Information Technology,
Surigao Del Norte State University,
Surigao City, Surigao Del Norte,
Philippines-8400

Abstract:- This study presents the development and evaluation of a Math Game Application for Toddlers that utilizes game-based learning to enhance early mathematical skills. Traditional teaching methods may not effectively engage young children, making educational games a valuable alternative. After conducting a comprehensive evaluation of the application, it can be concluded that the app is highly effective in terms of usability, relevance, functionality, maintainability, and critical thinking, with an overall average rating of 4.48, which is very satisfactory. The well-designed user interfaces, customizable feedback features, and wide range of interactive games make it an excellent tool for enhancing early mathematical skills in toddlers and preschoolers. Furthermore, the app's user-friendly interface and interactive gameplay provide an engaging and enjoyable experience for toddlers, making it an effective learning tool for parents and educators. The research demonstrates that the Math Game App for Toddlers has the potential to become a valuable tool in early childhood education, contributing to the development of future generations of young learners with strong mathematical skills.

Keywords: Mobile Applications, Math Game Apps, Educational Technology, Game-Based Learning.

I. INTRODUCTION

Mathematical skills are crucial for success in both academic and real-life settings, making it essential to introduce children to math at an early age. Toddlers, in particular, are at a critical stage in their cognitive and intellectual development, where early exposure to math can lay a strong foundation for their future academic success. With the increasing prevalence of digital devices in young children's lives, the use of technology can provide an engaging and effective way to teach math skills to toddlers.

Early exposure to mathematical concepts and operations is crucial for building a strong foundation for future academic pursuits. However, traditional teaching methods may not be effective in engaging young children, particularly toddlers and preschoolers. Educational games

offer an alternative approach that can enhance children's mathematical skills through fun and interactive activities.

Mobile applications have emerged as a popular platform for game-based learning due to their ubiquity and accessibility. There is a growing demand for educational games on mobile platforms, particularly for young children. However, there is a dearth of high-quality educational games targeted toward toddlers and preschoolers.

To this end, this study aims to develop and evaluate a math game application that enhances early mathematical skills through digital play for toddlers. The application focuses on interactive and age-appropriate games that cover various mathematical concepts, such as counting, shapes, and patterns. The study evaluates the application's effectiveness in enhancing toddlers' mathematical skills and explores its usability and user satisfaction among both toddlers and their caregivers.

The findings of this study have significant implications for early childhood education and the use of technology to enhance learning outcomes. The development of an effective math game application for toddlers can provide a fun and engaging learning experience, laying a strong foundation for their future academic success.

➤ Background of the Study

Mathematical skills are essential for academic and professional success, and it is important to begin developing these skills early in life. Research has shown that early math skills are strong predictors of later academic achievement [1][2]. Children who enter school with strong math skills are more likely to perform well academically, and are more likely to pursue careers in science, technology, engineering, and math (STEM) fields [3]. Furthermore, children who have a strong foundation in math are better equipped to develop more advanced mathematical skills later in life [4].

Technology-based learning has been shown to be an effective tool for teaching young children math skills [5]. One study found that computer-based math games were effective in improving young children's math skills [6]. Similarly, another study found that the use of an iPad app improved children's understanding of fractions [7].

Technology-based learning can be particularly effective for young children, as it can provide a visual and interactive learning experience [5].

Given the potential benefits of technology-based learning, several researchers have developed math games and apps for young children. For instance, the Math Doodles app [8] has been shown to improve young children's mathematical skills. Similarly, the DragonBox series of games developed by WeWantToKnow has been shown to be effective in teaching algebraic concepts to young children [9].

Math game mobile applications for toddlers have several benefits, including cognitive development, problem-solving skills, spatial reasoning, and number sense. These benefits have been demonstrated in several studies.

Math games can enhance cognitive functions such as attention, memory, and processing speed [10]. In a study by Chuang and Chen, preschoolers who played a math game app showed significant improvements in visual attention and processing speed compared to those who did not play the app [11].

Moreover, math game apps can also improve problem-solving skills in young children [12]. By solving math problems in a game format, children learn to think critically and logically, developing important problem-solving skills.

In addition, math games can also help develop spatial reasoning skills, which are important for math and science learning [13]. In a study by Suk and Son, preschoolers who played a math game app showed significant improvements in spatial reasoning compared to those who did not play the app [10].

Furthermore, math games can foster a strong understanding of number concepts in young children [13]. By participating in games that involve counting, recognizing numbers, and basic arithmetic, children can develop a solid foundation of number sense.

There are many math game mobile applications available for toddlers. Some examples include Endless Numbers, Math Kids, Endless Numbers, Math Playground, Splash Math, and Moose Math. Basically, these apps teach children numbers, basic arithmetic, and math concepts through fun and engaging interactive games and animations.

While math game mobile applications can offer many benefits, it is important also to consider their limitations. Excessive screen time has been linked to negative effects on children's health and development [15]. Therefore, it is crucial for parents and educators to closely monitor the amount of time children spend playing math game apps and ensure they are not overusing them.

Furthermore, it is important to recognize that math game apps may not provide the same level of social interaction and communication as traditional learning

methods. Young children need opportunities to interact with peers and adults to develop social and emotional skills that are crucial for their overall development.

Additionally, it is important to note that math game apps may not be able to address the individual needs of each child. Some children may require additional support or accommodations to fully comprehend math concepts. Therefore, while math game apps can be a helpful tool, they should not be relied upon as the sole method for teaching math to children.

The development of the Math Game Application for Toddlers involved the use of agile software development methodologies.

The researcher adopted a rapid application development methodology to plan, design, and implement the system. The app was built using modern software development tools and programming languages. The app was designed to run on popular mobile operating systems, such as Android and iOS.

Subsequently, an evaluation of the application's performance was conducted at the Hilltop Bible Baptist Learning Center in Surigao City, Philippines. They tested its various mathematical games at different levels and observed a positive response from the pupils who participated in the evaluation. Furthermore, the teachers at the center were able to use the application as administrators and perform tasks such as adding, editing, and deleting the mathematical questions that the researchers had initially created. This highlights the application's user-friendly interface and ease of use for both students and teachers alike.

➤ *System Diagram*

Figure 1 shows the components of the system. The user interface includes the graphical user interface (GUI) of the app, which provides an interactive and user-friendly interface for toddlers. It also includes colorful and attractive graphics, animations, and sound effects.

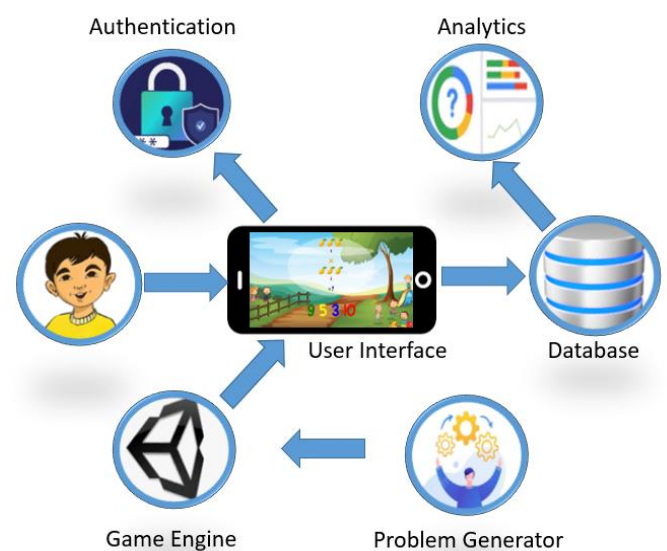


Fig 1 System Diagram

The game engine is responsible for managing the game mechanics, such as generating math problems, tracking the user's progress, and providing feedback on their performance. It also includes various difficulty levels based on the age and skill level of the toddler. The different math problems such as addition, subtraction, and counting, based on the difficulty level selected by the user are generated by the math problem generator. Moreover, the app has a database to store user data such as scores, progress, and other relevant information. The app also includes analytics and reporting capabilities that provide insights into the user's performance and help parents or guardians track their toddler's progress. Finally, the app has a login system to authenticate users and ensure the security of user data.

II. RESULTS

The researcher conducted interviews with the teachers at Hilltop Bible Baptist Learning Center in Surigao City, Philippines to gather data for the design of the system in line with determining project requirements.

Based on the gathered data, several key design considerations were identified to ensure the game effectively captures the attention of children. For example, the font size and style must be chosen carefully to ensure they are visible enough for young children to read easily. Additionally, for multiplication, the developer should consider using the "x" symbol instead of the asterisk (*) to make it more recognizable to children.

To enhance engagement, the game should incorporate the use of objects instead of numbers where possible. Lastly, the design should incorporate choices in a box or presented as clickable links as much as possible, to make the interface more user-friendly and easy for children to navigate.

➤ Design and Development

To capture the requirements of the system a use-case diagram was prepared for the app [16]. Figure 2 shows the design use-case diagram. It illustrates the various actions a user can take in the Math Game App. The user starts by initiating the app and then plays the game by answering math problems. The app checks if the user's answer is correct and either adds to the user's score or ends the game if the answer is incorrect. If the user answers correctly, the app moves on to the next question. If the timer runs out, the app ends the game automatically. After the game ends, the user can view their score or the leaderboard of high scores.

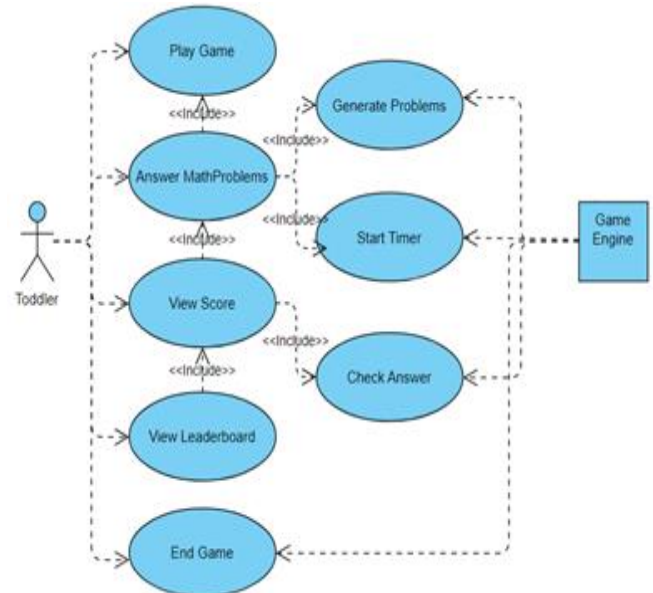


Fig 2 Design Use-Case Diagram

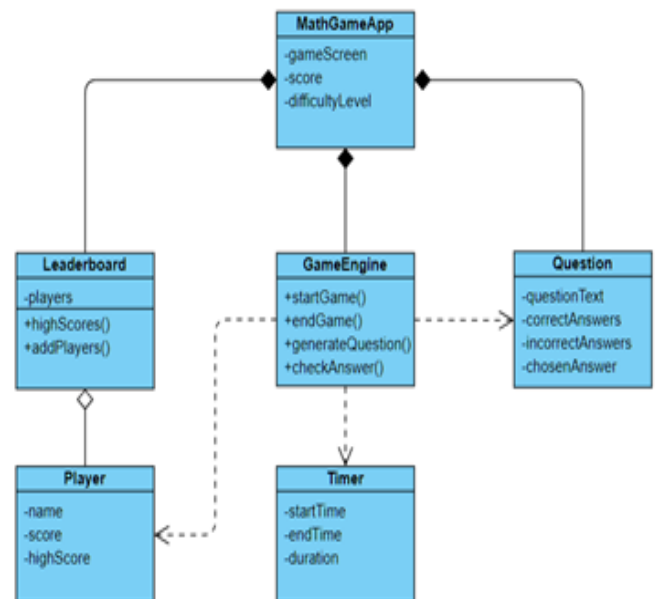


Fig 3 System Class Diagram

Figure 3 shows the class diagram to provide a visual representation of the system's architecture [17]. The following classes were used in the development of the app.

- *Math Game App*: This is the main class of the app, which includes variables such as the current game screen, the player's score, and the difficulty level. It also includes methods for initializing the game, updating the score, and changing the difficulty level.
- *Player*: This class represents the player of the game and includes variables such as the player's name, current score, and highest score. The class also includes methods for updating the player's score and retrieving the highest score.
- *Question*: This class represents the math problems that the player will solve in the game. It includes variables

such as the question text, the correct answer, and a list of incorrect answers. The class also includes a variable for the player's chosen answer and methods for generating a new question and checking the player's answer.

- *Game Engine*: This class is responsible for running the game and includes methods such as starting and ending the game, generating new questions, and checking the player's answers. It communicates with other classes such as Player and Question to update the game state.
- *Timer*: This class is responsible for timing the game and includes variables such as the start time, end time, and duration of the game. It includes methods for starting and stopping the timer and updating the duration of the game.
- *Leaderboard*: This class is responsible for keeping track of the highest scores achieved by players. It includes variables for a list of players and their scores, as well as methods for adding a new player and retrieving the highest scores.

➤ *The Math Game App*

The Math Game App for Toddlers has been designed with user-friendly interfaces to ensure that children can easily navigate through the app. The welcome and login screens, as shown in Figures 4 and 5 respectively, provide a visually appealing and engaging interface for children.

In order to ensure secure and personalized use of the app, users are required to enter their app credentials for authentication and progress monitoring. The login screen, in particular, serves as a gateway for users to access the app's features and track their progress. The app's credentials system helps to ensure the privacy of user information and progress data, providing parents and educators with peace of mind when using the app.



Fig 4 Welcome Screen



Fig 5 Login Form

Figure 6 provides an example of a math problem that toddlers can solve within one of the app's games. As shown in the figure, the toddler is presented with two numbers and is required to determine their sum. This is just one of the many interactive and engaging games that the Math Game App for Toddlers offers to help young children develop early mathematical skills.



Fig 6 Sample In-Game Math Problem

Figure 7 demonstrates the customizable feedback screen, which is a unique feature of the app. This feature allows parents and educators to provide personalized feedback to children based on their performance in the app. The feedback screen provides an opportunity to highlight areas for improvement, as well as praise children for their progress. The ability to customize feedback ensures that children receive specific and meaningful feedback that is tailored to their individual needs, providing them with motivation and a sense of accomplishment.



Fig 7 Customizable Feedback Screen



Fig 8 Game Level Screen

The game level screen to be used by the game engine for managing the game mechanics, such as generating math problems is shown in Figure 8.

➤ *App Evaluation*

The evaluation of the "Math Game Application for Toddlers" was conducted to assess its usability, relevance, functionality, maintainability, and critical thinking aspects. The evaluation aims to provide insights into the application's strengths and weaknesses to help improve the user experience and facilitate the learning process for toddlers. The evaluation was conducted by assessing the application's user interface, navigation, performance, customization, and feedback features. The results of the evaluation are as follows:

- *Usability:*

The Math Game App for Toddlers which was designed with usability in mind, as the user interfaces are intuitive and easy to navigate obtained an average usability score of 4.6 out of 5.0 from the evaluators. The app provided clear instructions for each game and includes a customizable feedback screen that allows parents and educators to provide personalized feedback to children based on their performance. This feedback feature ensures that the app is user-friendly, and children can easily engage with the app.

- *Relevance:*

The app is highly relevant, and rated an average of 4.5 out of 5.0 by the evaluators. It addresses the need for educational games that cater specifically to toddlers and preschoolers. With a focus on early mathematical skills, the app was designed to enhance children's learning through digital play. Furthermore, the app's customizable feedback feature ensures that it remains relevant and adaptable to individual children's needs.

- *Functionality:*

The Math Game App for Toddlers is highly functional and delivers on its intended purpose of facilitating early mathematical learning through interactive games. The app was rated an average of 4.4 out of 5.0 in terms of functionality. The app provides a variety of games that help children develop mathematical skills, such as counting, identifying arithmetic operations, and applying basic mathematical operations. Additionally, the app's feedback feature helps to ensure that children are making progress and receiving feedback that is tailored to their individual needs.

- *Maintainability:*

The app's average maintainability score is 4.4 out of 5.0. The app is easy to maintain, with a straightforward and well-organized code structure. The app's developers have included thorough documentation to facilitate ongoing maintenance and future updates. Furthermore, the app's customizable feedback feature ensures that it remains relevant and adaptable to individual children's needs.

- *Critical Thinking:*

The users also rated the Math Game App for Toddlers 4.5 out of 5.0. The app promotes critical thinking by presenting children with various problem-solving tasks that require them to apply basic mathematical operations. The app's interactive games encourage children to think critically and develop problem-solving skills while having fun. The app's feedback feature also helps to promote critical thinking by providing personalized feedback that highlights areas for improvement and encourages children to strive for progress.

After conducting the evaluation of the "Math Game App for Toddlers," it can be concluded that the application is highly effective in terms of usability, relevance, functionality, maintainability, and critical thinking, with an overall average rating of 4.48, which is very satisfactory. The app's well-designed user interfaces, customizable feedback feature, and wide range of interactive games make it an excellent tool for enhancing early mathematical skills

in toddlers and preschoolers. Additionally, the application's ability to engage and motivate children in the learning process is commendable. Overall, the Math Game App for Toddlers is a well-designed and effective application that provides an engaging learning experience for young children.

III. CONCLUSION

The study presents an effective and innovative way to enhance early mathematical skills in toddlers through game-based learning. The Math Game Application for Toddlers has demonstrated its usability, relevance, functionality, maintainability, and critical thinking skills, with an overall average rating of 4.48, indicating high user satisfaction. The app's user-friendly design, interactive gameplay, and customizable feedback features make it an excellent tool for enhancing young children's mathematical abilities.

The study's findings suggest that the Math Game App for Toddlers has the potential to become a valuable tool in early childhood education. By supplementing traditional teaching methods with this app, educators and parents can provide a more engaging and enjoyable learning experience for toddlers, promoting the development of strong mathematical skills.

In conclusion, the Math Game App for Toddlers has the potential to contribute significantly to the development of future generations of young learners. By fostering early mathematical skills through game-based learning, this app could help lay a solid foundation for children's academic success and future careers. Therefore, the development and evaluation of this app offers an excellent example of how technology can be used to improve early childhood education and contribute to building a brighter future for our children.

REFERENCES

- [1]. Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., ... & Japel, C. (2007). School readiness and later achievement. *Developmental psychology*, 43(6), 1428. <https://doi.org/10.1037/0012-1649.43.6.1428>
- [2]. National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*.
- [3]. Wang, M. T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational psychology review*, 29, 119-140.
- [4]. Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics* (Vol. 2101). National research council (Ed.). Washington, DC: National Academy Press.
- [5]. Clements, D. H., & Sarama, J. (2011). Early childhood mathematics learning. In *Handbook of research on the education of young children* (pp. 415-438). Routledge.
- [6]. Lieberman, D. A., Bates, C. H., & So, J. (2009). Young children's learning with digital media. *Computers in the Schools*, 26(4), 271-283.
- [7]. Simms, V., McKeaveney, C., Sloan, S., & Gilmore, C. (2019). Interventions to improve mathematical achievement in primary school-aged children.
- [8]. Carstens, A., & Beckmann, J. F. (2016). Math Doodles: A design and evaluation study of a digital math game for young children. *Computers & Education*, 95, 227-242.
- [9]. Fyfe, E. R., Matthews, P. G., Amsel, E., McEldoon, K. L., & McNeil, N. M. (2018). Assessing formal knowledge of math equivalence among algebra and pre-algebra students. *Journal of Educational Psychology*, 110(1), 87.
- [10]. Suk, S. H., & Son, Y. A. (2018). The effects of playing mathematics mobile games on elementary students' cognitive ability and math achievement. *Interactive Learning Environments*, 26(7), 881-894.
- [11]. Chuang, T. Y., & Chen, F. C. (2017). Effects of playing an educational game on preschoolers' visual attention and processing speed. *Educational Technology & Society*, 20(2), 49-59.
- [12]. Fuson, K. C., Smith, S. T., & Lo Cicero, A. M. (2016). Young children's learning from touchscreens: Finding and evaluating events. *Journal of Experimental Child Psychology*, 146, 14-35.
- [13]. Halberda, J., Mazocco, M. M., & Feigenson, L. (2008). Individual differences in non-verbal number acuity correlate with maths achievement. *Nature*, 455(7213), 665-668.
- [14]. Valtchanov, D., Nokes-Malach, T. J., & Thompson-Schill, S. L. (2016). The benefits of learning from a complex training game for mathematics education. *PLoS ONE*, 11(3), e0151419.
- [15]. American Academy of Pediatrics. (2016). Media and young minds. *Pediatrics*, 138(5), e20162591.
- [16]. Mule, S. S., Waykar, Y., & Mahavidyalaya, S. V. (2015). Role of USE CASE diagram in s/w development. *International Journal of Management and Economics*.
- [17]. Nikiforova, O., Sejans, J., & Cernickins, A. (2011). Role of UML Class Diagram in Object-Oriented Software Development. *Sci. J. Riga Tech. Univ. Ser. Comput. Sci.*, 44, 65-74.