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Arithmio: A Mobile Game-Based Learning Application to Support Parental Engagement in Early Mathematics Education

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Abstract

This paper presents the development and design of Arithmio, a mobile game-based learning (MGBL) application aimed at supporting parents in teaching basic mathematics to their children. The application utilizes interactive gameplay and engaging scenarios to deliver arithmetic concepts in a fun and meaningful way, particularly for early learners who may struggle with traditional instructional approaches. By incorporating gamification elements such as character selection, narrative dialogues, real-life transactional tasks, and progressive scoring mechanisms, Arithmio not only enhances mathematical comprehension but also promotes positive learning experiences and motivation among children. The application adapts the GAMED methodology to ensure a structured and pedagogically sound development process that aligns with educational goals. Supporting artifacts such as a storyboard, flowchart, use case diagram, and high-fidelity prototype were produced to guide the development lifecycle. The design of Arithmio also emphasizes parental involvement, allowing parents to participate in and monitor their child's learning journey, thereby strengthening the parent-child educational bond. Literature findings further corroborate the positive impact of MGBL on learning outcomes, student engagement, and parental participation. Overall, this study demonstrates how thoughtfully designed educational applications like Arithmio can bridge formal and informal learning environments, making mathematics learning more accessible, interactive, and effective.

Keywords: Mobile Game-Based Learning (MGBL) application, Mobile Learning and Technology, Educational Application, Mathematics Education

Introduction

Early mathematics education plays a critical role in developing foundational cognitive skills among children, particularly in numeracy and logical reasoning. However, traditional methods of teaching mathematics are often perceived as not engaging by young learners, leading to reduced motivation and limited retention of key concepts. In response to these challenges,

mobile applications have emerged as promising tools for transforming mathematics instruction into more interactive, enjoyable, and learner-centered experiences.

Among these technological innovations, mobile game-based learning (MGBL) applications have gained significant attention for their ability to integrate educational content with engaging gameplay. By leveraging the intrinsic motivational elements of games. These applications can enhance learners' engagement and foster deeper conceptual understanding. When appropriately designed, MGBL tools can serve as effective mediums for conveying mathematical concepts, especially at early childhood levels where attention spans are short and learning is highly experiential.

Equally important in early education is the role of parental involvement. Studies have consistently shown that when parents actively participate in their children's learning activities, academic performance and attitudes toward learning improve. MGBL applications designed with parental usability in mind can bridge this gap by offering accessible, user-friendly platforms that allow parents to facilitate learning at home. These tools not only support children's cognitive development but also promote stronger parent-child bonds through collaborative learning experiences.

Literature Review

Game-based learning applications utilize fun and interactive gameplay to engage children in mathematics, making learning enjoyable (Kwok et al., 2020). As children achieve goals within the game, parents can celebrate these milestones, strengthen the parent-child relationship, and encourage further involvement in learning (Kwok et al., 2020). Educational games help develop critical thinking and problem-solving skills, which parents can reinforce through discussions about game strategies and outcomes (Dawson et al., 2023). Applications designed for young learners can improve foundational numeracy skills, allowing parents to track progress and provide support where needed (Urquhart et al., 2023).

Many applications are designed to be user-friendly, enabling parents to easily engage with their children during gameplay, thus enhancing their confidence in teaching mathematics (Yabut et al., 2019). During situations like the pandemic, these applications serve as effective tools for parents to facilitate learning at home, ensuring continuity in education (Widjayatri et al., 2022). While these applications can enhance parental involvement, some parents may feel overwhelmed by technology or lack confidence in their math skills, potentially hindering their engagement in their child's learning process.

Studies have shown that children who use educational games for learning mathematics often exhibit improved understanding and retention of mathematical concepts (Aljojo, 2018) (Bantun et al., 2024).

While game-based learning applications offer numerous benefits, they also present challenges. Parents may struggle to evaluate the quality of available applications which can affect their ability to choose the most effective tools for their children (Urquhart et al., 2023). Additionally, excessive screen time and reliance on digital devices can be a concern, necessitating a balanced approach to technology use in education. Nonetheless, when used

appropriately, these applications can be a valuable tool in enhancing parental involvement and improving children's mathematical learning experiences.

Mobile game-based learning systems have been shown to improve students' learning achievements significantly. For instance, an interactive mobile math game with a help-seeking mechanism was found to enhance elementary students' mathematics performance, especially benefiting those with low self-efficacy in mathematics (Yang et al., 2022). The use of educational mobile games may result in a significant improvement in math achievement compared to traditional teaching methods (Alkhateeb, 2019). The development of gamified educational applications has also been effective in improving students' understanding of mathematical concepts (Bantun et al., 2024).

Game-based learning applications have been successful in increasing motivation among students. For example, the use of the Kahoot application in classrooms significantly boosted motivation and academic achievement among students (Jarrah et al., 2025). Mobile applications designed with gamification elements have been reported to enhance learning motivation by making the learning process more enjoyable and interactive (Bantun et al., 2024) (Yifan et al., 2024). The use of mobile games in mathematics education has also been shown to reduce math anxiety and foster a more positive attitude towards learning mathematics (Yifan et al., 2024).

This paper presents the development and design of Arithmio, a mobile game-based learning (MGBL) application aimed at supporting parents in teaching basic mathematics to their children. The application is designed in Bahasa Malaysia. The application utilizes interactive gameplay and engaging scenarios to deliver arithmetic concepts in a fun and meaningful way, particularly for early learners who may struggle with traditional instructional approaches. By incorporating gamification elements such as character selection, narrative dialogues, real-life transactional tasks, and progressive scoring mechanisms, Arithmio not only enhances mathematical comprehension but also promotes positive learning experiences and motivation among children. The application adapts the GAMED methodology to ensure a structured and pedagogically sound development process that aligns with educational goals. Supporting artifacts such as a storyboard, flowchart, use case diagrams and high-fidelity prototypes were produced to guide and validate the development lifecycle.

Methodology

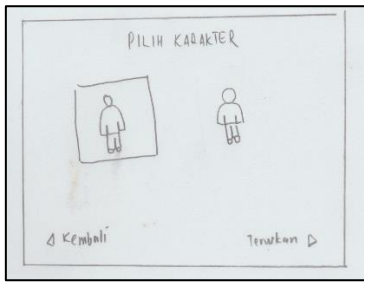
GAMED is embedded within a digital educational game life cycle, which organizes the phases, processes, and work products necessary for game development (Aslan & Balci, 2015). It includes quality assurance and project management activities to ensure the game meets educational and entertainment objectives (Aslan & Balci, 2015). The GAMED methodology offers a structured approach to developing digital educational games, addressing the complexities of integrating educational content with engaging gameplay (Aslan & Balci, 2015). It provides a comprehensive framework that guides developers through the entire life cycle of a digital educational game, from conception to retirement (Aslan & Balci, 2015). This methodology is essential for managing the multidisciplinary nature of game development, which involves expertise in areas such as digital graphic design, education, and software engineering. The GAMED methodology is designed to ensure that educational games are not only entertaining but also effective learning tools.

Results and Discussions

A. Game Design Using Storyboard

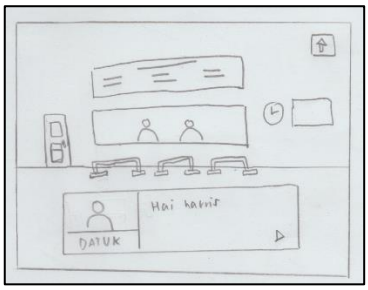
The Menu screen of Arithmio

Upon launching the application, users are greeted with the main menu screen, which provides intuitive navigation through four primary options: *Mula Permainan* (Start Game), *Pencapaian* (Achievements), *Tutorial,* and *Keluar* (Exit). Each button leads to a different functional component of the application. The Mula Permainan button initiates gameplay, Pencapaian displays the user's progress and achievements, Tutorial offers guidance on how to play, and Keluar exits the application.



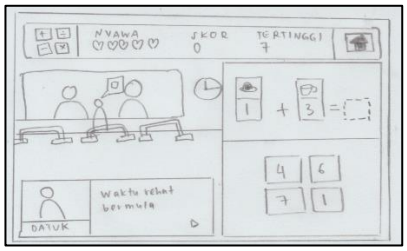
***Pilih Karakter* (Choose Character) screen of Arithmio**

Selecting Mula Permainan directs the user to the Pilih Karakter (Character Selection) screen. Here, players can choose between two avatars (Harris or Sarah) and navigate back to the main menu using the *Kembali (*Back) button or proceed to gameplay via the Teruskan button. This screen adds a personalized dimension to the learning experience, enhancing user engagement.



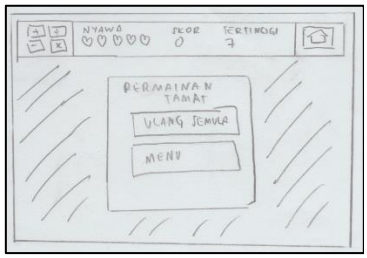
The Introduction scene in Arithmio

The introduction scene follows the character selection. It features a dialogue-driven interaction between the chosen character and an in-game mentor figure, *Datuk* (Grandfather). This scene establishes the game's narrative context which is set in a school canteen and introduces the educational objective of assisting *Datuk* in handling basic arithmetic-based transactions. Players navigate through this dialog using an arrow button, preparing them for the tasks ahead.



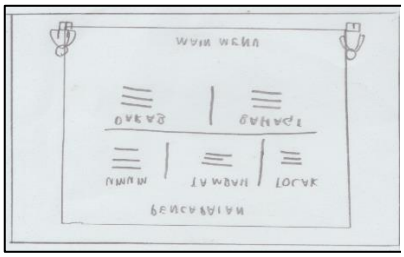
The game scene in Arithmio

After the introduction, players enter the main gameplay scene, which forms the core learning environment. Here, users engage in solving arithmetic problems (addition, subtraction, multiplication, and division) through contextualized scenarios involving customers and purchases at a virtual school canteen. The interface displays visual items such as food or currency, and the player is



The Game over screen in Arithmio

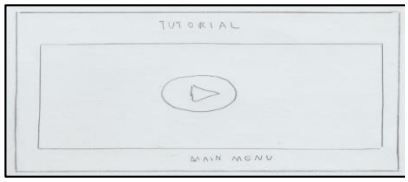
Once a player exhausts their life, a Game Over screen appears, offering two options: *Ulang Semula* (Restart) or *Menu* (Return to Main Menu). This allows users to either attempt the game again or exit to the home interface.



The *Pencapaian* (Achievement) screen in Arithmio

From the main menu screen, this screen will be shown when the player clicks the *Pencapaian* (Achievement) button and the player can return to the main menu by clicking the Main Menu button at the bottom of the screen.

required to calculate values and use a drag-and-drop mechanism to select the correct answers. Immediate feedback is provided through a scoring system and life counter; incorrect answers reduce the number of available lives. When all lives are lost, the game ends.



Tutorial screen in Arithmio

This flow is similar to the previous one, the Pencapaian screen where the player can access it by clicking the Tutorial button and also return to the menu by tapping the Main Menu button.

Fig. 1 Storyboard

Fig. 1 depicts the storyboard. The design of Arithmio is structured around a storyboard framework that outlines the visual flow and functional interactions within the application. The storyboard serves as a blueprint to guide the user experience and interface design, ensuring that educational and engagement objectives are effectively embedded throughout the gameplay.

B. Flowchart

Fig. 2 shows the flowchart. The process of *Mula Permainan* (Start Game) begins with launching the game. As soon as the game is launched, the game menu will be presented where the player can click the *Mula Permainan* (Start Game) button. If the button is not clicked, the player will remain on the same page. As soon as the *Mula Permainan* button is clicked, the game will show the character screen and the player can select which character they want to play with from the available two characters which are *Harris* and *Sarah*. After that, the player will proceed to the introduction screen where *Datuk* (Grandfather) will greet and give some briefing about the importance of Mathematic and how the player can help *Datuk* in the school canteen to be involved in a transactional situation. Navigating through the dialog and finally, the player can proceed to play the game. As an output, it will tell the current score, the highest score, and how many lives are available. Players can play until the number of lives turns to zero or click the home button if they wish to exit the game.

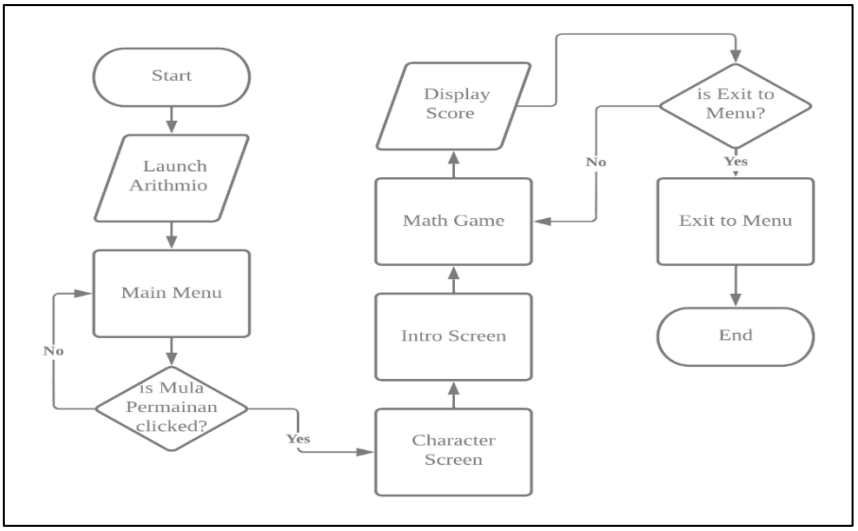


Fig. 2 Application flowchart

C. Use Case Diagram

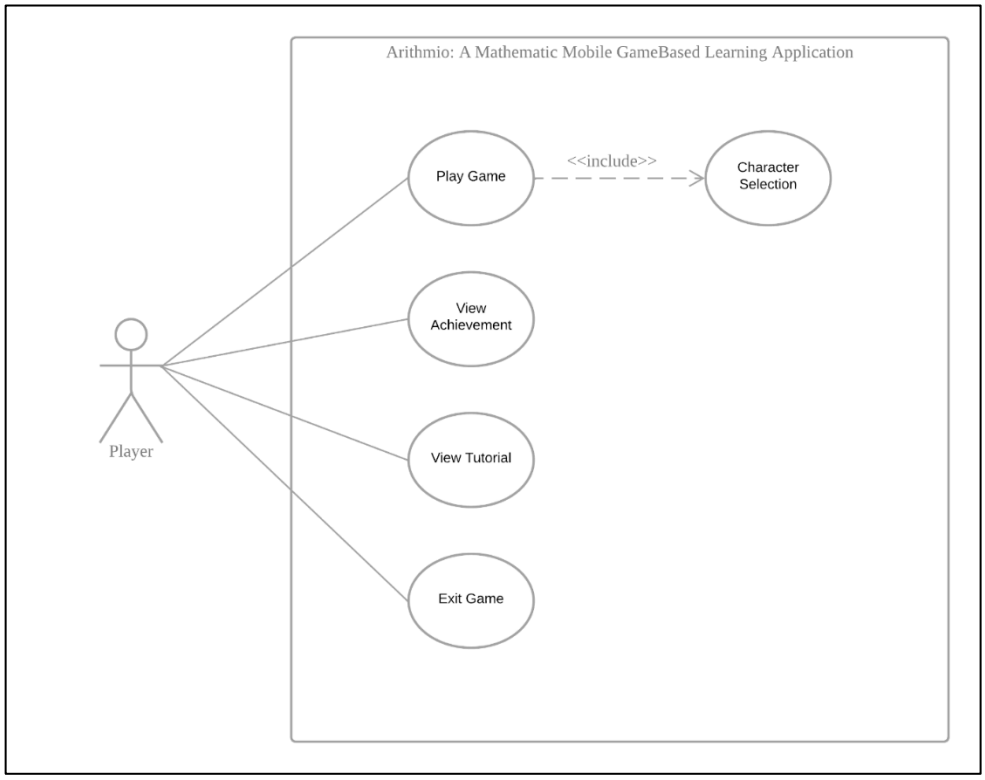


Fig. 3 Use case diagram for the application

Fig. 3 depicts the use case diagram of the application. There are four use cases:

- **Play Game**: This use case includes several scenarios such as character selection, introduction scene, game scene, and game over scene. Every time the play game function is initiated, these scenarios will also be included.
- **View Achievement**: This is a standalone use case, but the statistics are based on the data obtained from playing the game.
- **View Tutorial**: Also, a standalone use case meant to provide help and guidance to the player on how to operate the game.
- **Exit Game**: Allow the player to exit from Arithmio.

The only actor in Arithmio is the player, who is those humans who play when interacting with the game. The player interacts with the Arithmio game by playing the game and choosing a character, viewing achievements, and watching the tutorial. The player also decides whether to exit the game or not by tapping the *Keluar* (Exit) button from the main menu. Thus, the use case diagram shows that the actor has a relationship with four use cases of the game: (i) Play Game, (ii) View Achievement, (iii) View Tutorial, and (iv) Exit Game.

D. High-fidelity Prototype

Fig. 4 Menu screen in Arithmio

Fig. 4 shows the four buttons on the main menu screen and those buttons are (i) *Mula Permainan* (Start Game), (ii) *Pencapaian* (Achievement), (iii) *Tutorial*, and (iv) *Keluar* (Exit).

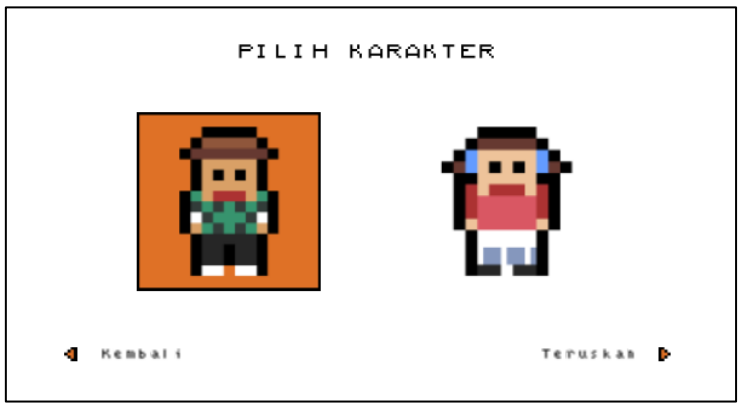


Fig. 5 *Pilih Karakter* (Choose Character) screen in Arithmio

Fig. 5 shows the character selection screen and by tapping the character, the player can switch between *Harris* or *Sarah*. The player can return to the home page by clicking the *Kembali* (Back) button located on the left-hand side and if they wish to proceed, they can click the *Teruskan* (Continue) button.

Fig. 6 Introduction scene in Arithmio

Fig. 6 shows the introduction scene. At this point, the character selected can be seen standing behind the counter. *Datuk* (Grandfather) will greet the player and the player will be asked to help *Datuk* in the transaction process (buying and selling process) at the school canteen. *Datuk* will also explain the benefits and importance of learning Mathematics in human's daily lives and that there are four basic arithmetic to be mastered and those are adding, subtracting, multiplying, and dividing.

Fig. 7 Game scene in Arithmio

Fig. 7 shows the Game Scene. This is the core interface of the game called the game scene. This screen is where the player will spend most of their time solving the Mathematical problem which is represented in the 'buying' and 'selling' situations at the school canteen. Each customer will come towards the counter expressing their want using a small dialog box. For example, a customer wants a cup of coffee. Through the dialog box, *Datuk* will help the player by explaining how much the coffee costs and the player can start answering the question by dragging any correct answer into a dashed-line box. A correct answer will count as one point and a wrong answer will deduct the number of lives by one. After the number of lives turns to zero, a small window will pop up indicating that the game is over, and the player has two options either restart the game or return to the game menu. The highest score will be updated every time the current score exceeds the highest.

Conclusion

This study presents the development and design of Arithmio, a mobile game-based learning (MGBL) application tailored for parents to actively participate in teaching basic arithmetic to their children. The integration of educational content with interactive gameplay provides a compelling alternative to conventional mathematics instruction, especially for early learners. Arithmio leverages engaging narrative elements, character selection, gamified interactions, and real-life transactional scenarios to foster mathematical thinking in a child-friendly environment.

The literature review supports the efficacy of MGBL applications in enhancing learners' motivation, improving conceptual understanding, and reducing anxiety towards mathematics. In this context, Arithmio addresses the critical role of parental involvement by offering a platform where parents can support and monitor their child's progress in a meaningful way. The storyboard, flowchart, use case diagram, and high-fidelity prototypes demonstrate the careful consideration given to the development process.

The application design, guided by the adapted GAMED methodology, ensures that educational value is systematically integrated into each phase of development. This structured approach underlines the multidisciplinary collaboration required to produce effective educational technology. Although promising, future iterations of Arithmio should consider broader usability testing, integration of adaptive learning algorithms, and support for diverse mathematical competencies to enhance scalability and inclusivity. Ultimately, Arithmio serves as a practical tool to bridge formal and informal learning spaces, promote collaborative learning between parents and children, and enrich early mathematical education through mobile technology.

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