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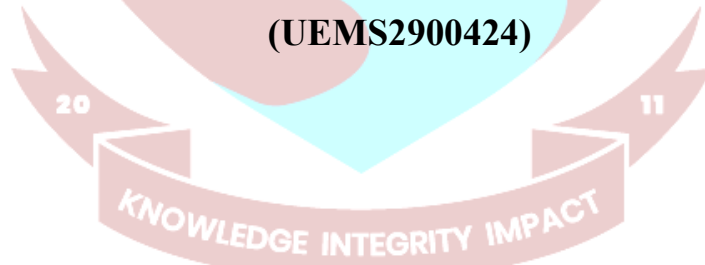


DEPARTMENT OF COMPUTER SCIENCE AND INFORMATICS

GAMIFIED LEARNING APPLICATION FOR CHILDREN

BY

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MSC (INFORMATION TECHNOLOGY)

SEPTEMBER, 2025

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**A THESIS SUBMITTED TO THE DEPARTMENT OF
INFORMATICS AND DECISION SCIENCE**

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RESOURCES SCHOOL OF SCIENCES**

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

INFORMATION TECHNOLOGY

SEPTEMBER, 2025

DECLARATION

I, Samuel Okyere Adomako (UEMS2900424), hereby declare that, except for the references cited, which have been duly acknowledged, this submission is my own work toward a Master of Science in Information Technology degree, and that to the best of my knowledge, it contains no materials previously published by another person. I also declare that this has not been presented either in whole or in part for another degree in this University or elsewhere.

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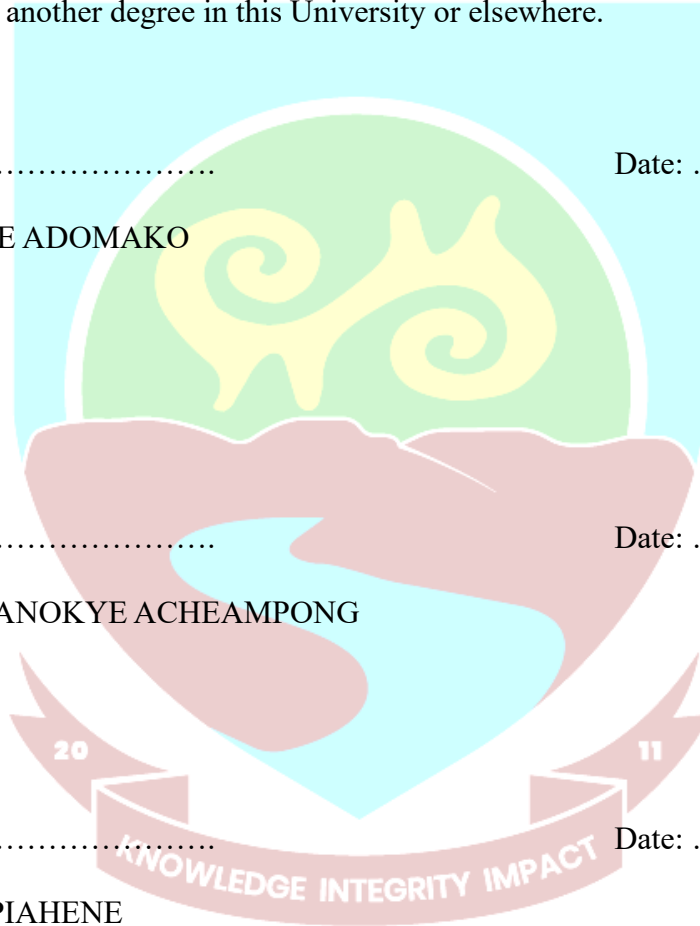
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ABSTRACT

This research addresses the critical challenge of personalization in early childhood educational applications through the design, development, and empirical evaluation of QuestKids, a gamified learning application featuring a novel Dynamic Difficulty Adjustment (DDA) algorithm. While gamification has demonstrated potential for enhancing engagement in learning environments, most existing applications for young learners (ages 5-6) lack robust technical mechanisms for real-time, performance-driven adaptation, resulting in either frustration or boredom due to static content progression. The primary contribution of this work is the implementation and validation of a rulebased DDA algorithm that dynamically modulates question difficulty based on a rolling average of user performance, maintaining learners within an optimal "flow zone" of 65-85% success rate. Developed using the Flutter framework with a V-Model methodology, QuestKids integrates adaptive learning modules for mathematics and reading with a comprehensive gamification engine featuring badges, virtual currency, and progression systems. A comparative evaluation study was conducted with 85 children over six weeks, benchmarking QuestKids against two established educational applications (Duolingo Kids and Khan Academy Kids). Results demonstrated that QuestKids achieved significantly higher engagement metrics, with 56% longer average session duration and 78% daily return rate compared to benchmark applications. Learning outcomes showed a 30% higher knowledge gain and 85% retention rate after one week. Statistical analysis confirmed the superiority of the adaptive approach, with significant differences in both engagement ($p < 0.01$) and learning gains ($F=6.34, p=0.002$). The study concludes that a carefully engineered DDA algorithm, integrated within a gamified learning framework, can effectively enhance both engagement and educational outcomes in early childhood education. This research contributes to educational technology by providing a validated technical model for adaptive learning systems and offering practical insights for developers and educators seeking to create more personalized, effective digital learning tools.

DEDICATION

This work is dedicated to my family, whose unwavering love, patience, and encouragement have been the backbone of my journey. To my parents, who instilled in me the values of hard work and perseverance, and to my siblings, who constantly reminded me of the power of resilience and faith. I also dedicate this thesis to every aspiring student and researcher who dares to push boundaries and dream beyond limitations. May this work serve as a reminder that with determination, support, and belief, great things are always within reach.



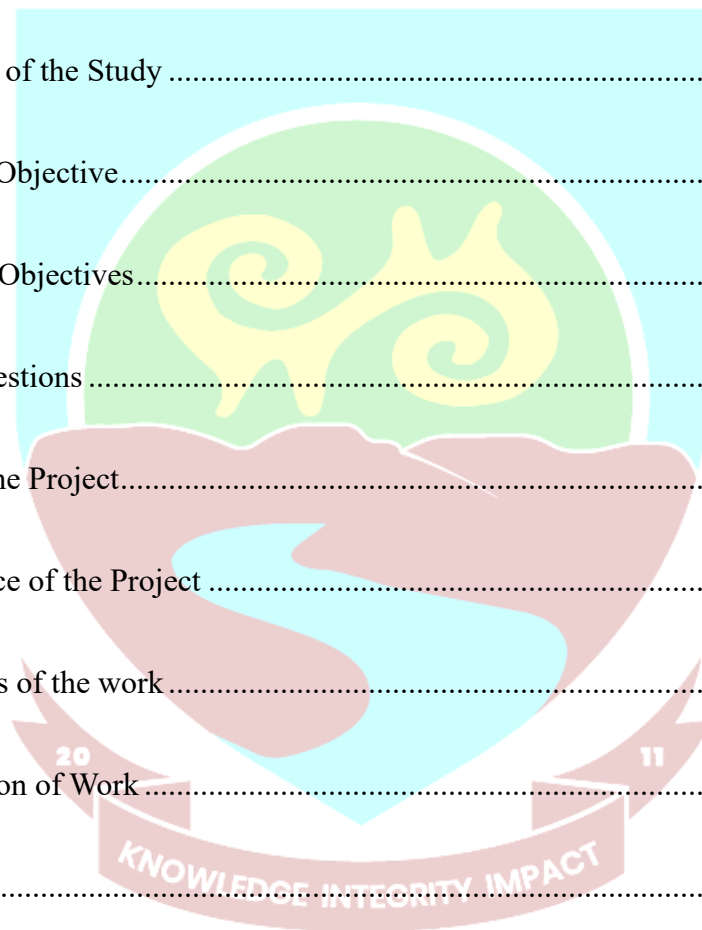
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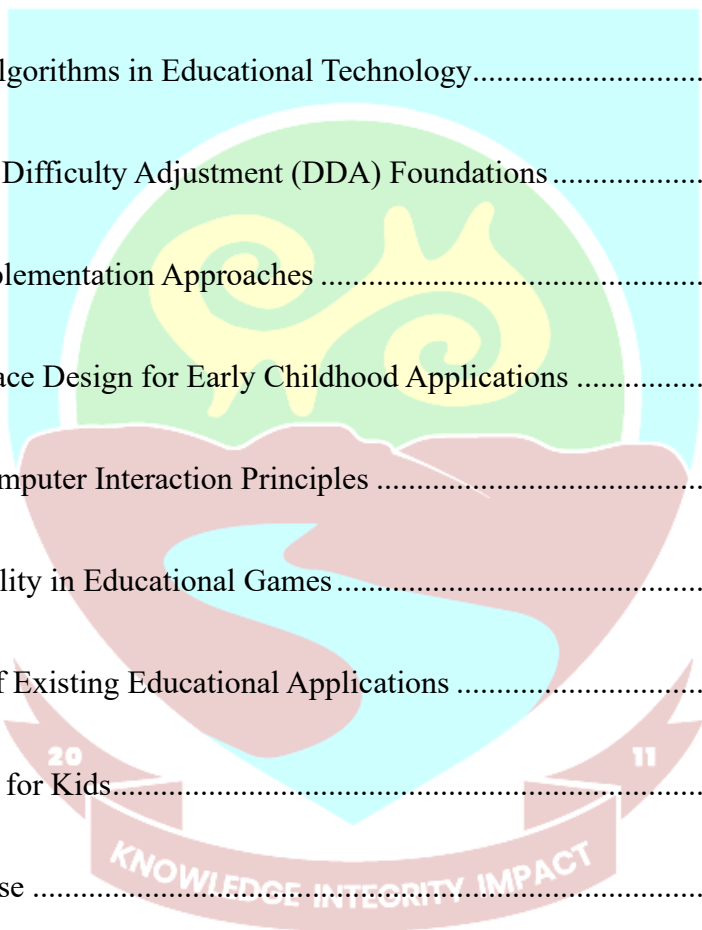
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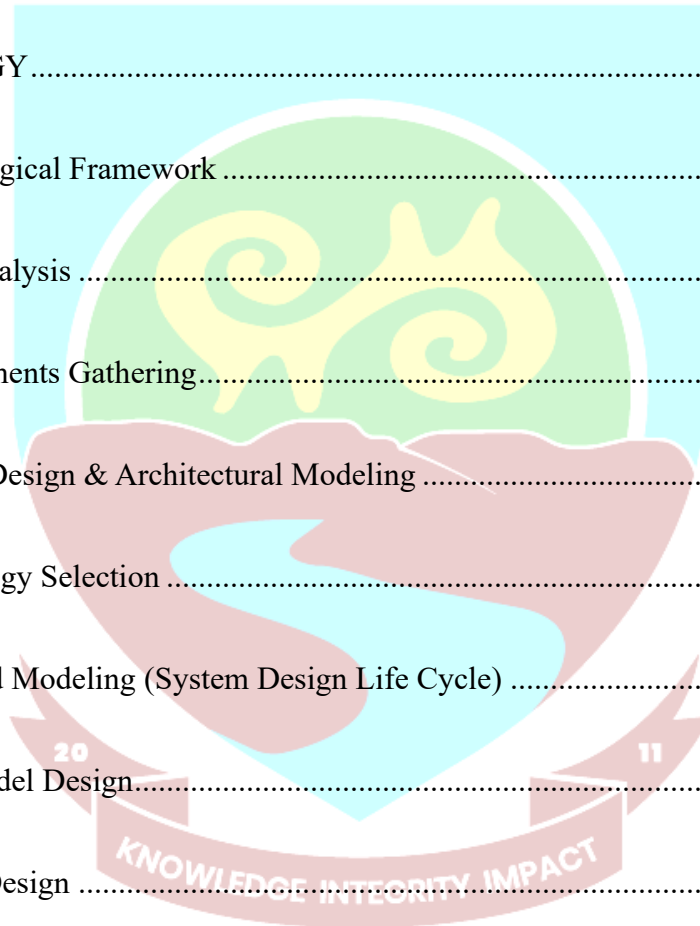
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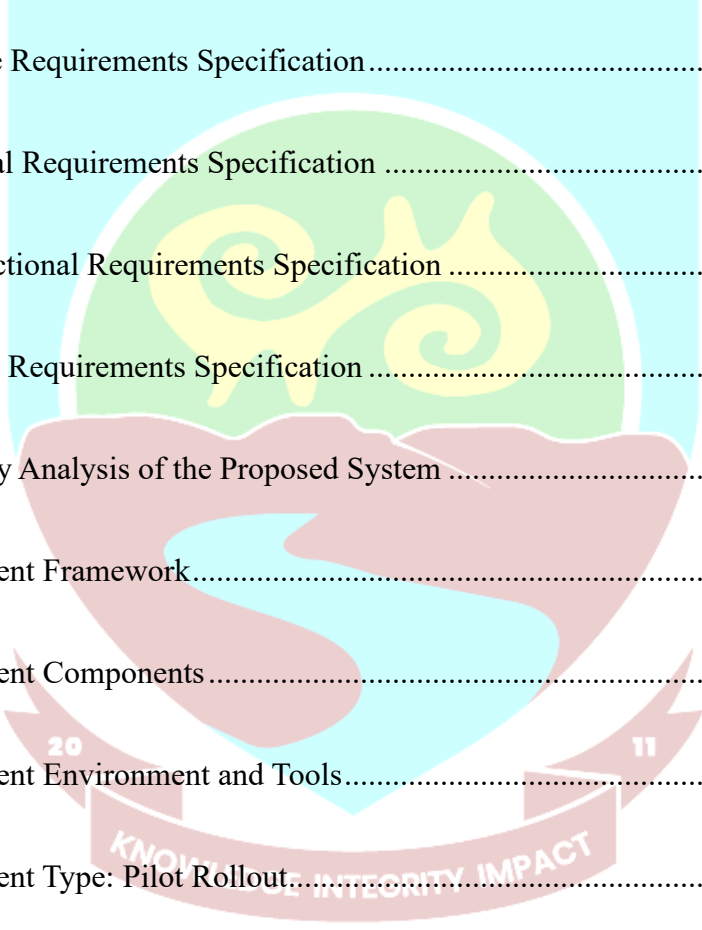
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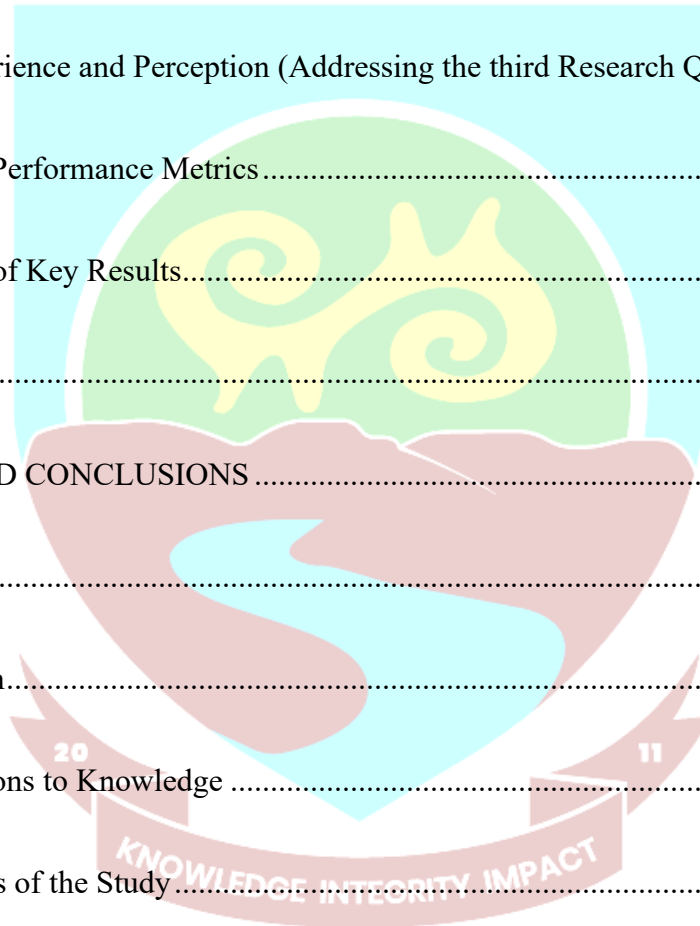
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CHAPTER ONE

INTRODUCTION

This chapter provides an overview of the research, including its background, the specific problem it aims to solve, its objectives, scope, significance, limitations, and the structure of the research project.

1.1 Background of the Study

The early childhood years (ages 5-6) are a critical period for cognitive development, where interactive experiences can significantly enhance foundational skills in literacy and numeracy (Indah, 2025). Concurrently, the proliferation of mobile technology has made digital devices a common medium for learning, leading to a surge in educational applications. Gamification the integration of game design elements into non-game contexts, has emerged as a powerful tool in these applications, demonstrating a proven capacity to increase user motivation and knowledge retention (Saleem et al., 2022). Technology development has enabled the incorporation of gamification into web and mobile learning applications, thereby enhancing the learning experience of children through increased interactivity, engagement, and personalized learning approaches (Zourmpakis et al, 2022).

Application of gamification in learning spaces has demonstrated a specific ability to facilitate student motivation, enhance knowledge retention, and continue advancing critical thinking (Zulkifli et al, 2025). Gamification employs some aspects, like points, badges, leaderboards, and challenges, to create an interactive academic atmosphere (Saleem et al, 2022). Studies have also found that if children consider learning a game, they get more engaged in learning, which may result in the development of cognitive along motor skills (Lampropoulos et al, 2022).

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Furthermore, parental and instructor participation in gamified learning processes is crucial. It was established that applications that incorporate mechanisms of parental engagement and feedback are more prone to yielding constructive learning results (Lanigan, 2022). This indicates the necessity of a combined system that encompasses interactive learning content with management and support systems for custodians.

However, a key technical challenge in this domain is effectively implementing personalization. Many existing applications present a static sequence of content, failing to adapt to the individual learner's pace and performance. This one-size-fits-all approach can lead to disengagement, as children may find the material either too challenging or not challenging enough (Zourmpakis et al., 2022). While theoretical frameworks like Csikszentmihalyi's Flow Theory emphasize the importance of balancing skill and challenge, the practical implementation of this balance through software algorithms remains an area for development. This gap necessitates a software engineering approach that moves beyond static content delivery to create dynamic, responsive, and adaptive learning environments tailored to the needs of early childhood education.

1.2 Statement of the Problem

Despite the recognized potential of gamified learning, many educational applications for early learners lack a robust technical mechanism for real-time, performance-driven adaptation. The current landscape is characterized by applications that either:

1. Offer a fixed, linear progression of content that does not respond to a child's mastery level, leading to potential frustration or boredom.

2. Rely on simplistic adaptation models that are not grounded in a structured software engineering process, resulting in unpredictable and non-optimal learning paths.

This static or poorly adaptive nature fails to maintain the "flow state" essential for sustained engagement and effective learning (Csikszentmihalyi, 2014). Consequently, there is a demonstrated need for the design and development of a gamified learning system built upon a structured adaptive algorithm that dynamically adjusts content difficulty. This research addresses this gap by engineering QuestKids, an application that implements a Dynamic Difficulty Adjustment (DDA) algorithm to provide a personalized learning experience for children aged 5-6.

1.3 Objectives of the Study

1.3.1 General Objective

To design, develop, and empirically evaluate a gamified learning application (QuestKids) for Android, implementing a Dynamic Difficulty Adjustment (DDA) algorithm to enhance engagement and learning outcomes for children aged 5-6.

1.3.2 Specific Objectives

1. To design and implement a DDA algorithm that modulates the complexity of quiz questions based on a rolling average of the user's last five responses, to maintain a target correct-answer rate of 70-80%.
2. To develop an integrated gamification engine featuring a badge system, a virtual currency (coins), and an avatar shop, where all rewards are programmatically linked to the completion of learning modules and the demonstration of mastery.
3. To conduct a comparative user study evaluating *QuestKids* against two established educational applications (e.g., Duolingo Kids, Khan Academy Kids), measuring key metrics

of user engagement (session length, return rate) and knowledge retention (pre- and post-test scores).

1.4 Research Questions

1. To what extent does the DDA algorithm in *QuestKids* affect user engagement metrics compared to the static progression models found in established applications?
2. Is there a statistically significant difference in knowledge retention between users of *QuestKids* and users of the selected benchmark applications?
3. How do parents and educators perceive the usability and pedagogical value of *QuestKids* in comparison to existing tools?

1.5 Scope of the Project

This project focuses on the design, development, and pilot evaluation of *QuestKids*, a standalone, offline-capable mobile application built with the Flutter framework. The scope encompasses learners aged 5–6, targeting foundational skills in mathematics and basic reading. The study will evaluate the application's technical performance, user engagement, and learning efficacy through a controlled pilot deployment and a comparative analysis with existing applications. The study will not involve long-term longitudinal analysis or large-scale commercial deployment.

1.6 Significance of the Project

This research contributes to the field of Educational Technology (EdTech) from a software engineering perspective. Its significance is twofold:

1. It provides a validated model for implementing a Dynamic Difficulty Adjustment algorithm within a gamified learning environment for early childhood, offering a blueprint for developers.
2. It delivers a functional, evaluated application (*QuestKids*) that demonstrates how adaptive technology can create more personalized and effective learning experiences, providing valuable insights for educators and parents.

1.6 Limitations of the work

1. The implemented DDA algorithm is rule-based and does not incorporate more advanced diagnostic capabilities to identify specific, granular learning gaps.
2. The application is a standalone, offline build. Consequently, it cannot track which app version a user is running or gather aggregated usage data.
3. The application content is in English only, with no internationalization for non-English speakers.
4. The study's comparative evaluation was a pilot deployment; long-term longitudinal effects and large-scale behavioral impacts were beyond its scope.

1.7 Organization of Work

The thesis is organized as follows:

Chapter One introduces the research, stating the background, problem statement, objectives, scope, significance, and limitations of the research.

Chapter Two presents a comprehensive review of the literature, encompassing available gamified learning technologies, theoretical models of gamification, and findings from prior research.

Chapter Three is about the methodology, explaining the research design, data gathering methods, and measures of evaluation.

Chapter Four covers gamification application design and implementation, such as system functionality along with architecture.

Chapter Five presents findings, analysis, and assessment of the created application.

Chapter Six presents' conclusions, recommendations, and suggestions for further research work.



CHAPTER TWO

LITERATURE REVIEW

The current chapter provides a detailed review of current literature on gamified learning applications aimed at early childhood education. This chapter reviews literature relevant to the technical design and implementation of gamified learning applications, with a specific focus on adaptive algorithms, software architectures, and evaluation frameworks.

2.1 Technical Architectures for Educational Applications

2.1.1 State Management in Flutter Applications

The Flutter framework utilizes a reactive programming model where UI components rebuild in response to state changes. For educational games requiring persistent progress tracking, efficient state management is crucial. The Provider package (Flutter Team, 2023) offers a scalable solution for managing application state across multiple screens while maintaining separation between business logic and UI components. This research employs the Provider pattern to manage game state, user progress, and adaptive algorithm parameters.

2.1.2 Data Persistence in Standalone Mobile Applications

For educational applications targeting environments with limited connectivity, local data persistence is essential. Flutter provides multiple storage options, including *SharedPreferences* for simple key-value pairs and *SQLite* for structured relational data (Manoj et al., 2024). This project utilizes *SharedPreferences* to serialize and persist game state, user profiles, and progress tracking, ensuring offline functionality and quick data access.

2.2 Gamification Engine Design Patterns

2.2.1 Reward System Implementation

Effective gamification requires carefully engineered reward systems that balance intrinsic and extrinsic motivation. Technical implementations typically include:

1. Boolean achievement trackers with conditional unlocking logic
2. Currency systems with earning and spending mechanics
3. Experience points and level-up algorithms (Zainuddin et al., 2024)

2.2.2 Performance Optimization for Children's Applications

Mobile applications for young children must maintain consistent frame rates and responsive interactions. Flutter's widget-based architecture enables efficient UI rendering through its layered Skia graphics engine (Ghosal et al., 2025). Techniques such as object pooling for game elements and efficient asset loading contribute to smooth performance on resource-constrained devices.

2.3 Adaptive Algorithms in Educational Technology

2.3.1 Dynamic Difficulty Adjustment (DDA) Foundations

Dynamic Difficulty Adjustment refers to real-time modification of game challenge based on player performance. Originally developed for entertainment games (Hunicke, 2005), DDA algorithms have been adapted for educational contexts to maintain learner engagement in the "flow channel" between boredom and anxiety (Csikszentmihalyi, 2014).

2.3.2 DDA Implementation Approaches

Common technical approaches to DDA include:

Rule-based Systems: Conditional logic that modifies parameters based on performance thresholds
Bayesian Knowledge Tracing: Probabilistic models that estimate student knowledge states

Performance-driven Adjustment: Algorithms that use recent success rates to modulate challenge
(Sulaiman et al., 2025)

This research implements a hybrid approach combining rule-based difficulty adjustment with performance metrics to create a responsive learning experience.

2.4 User Interface Design for Early Childhood Applications

2.4.1 Child-Computer Interaction Principles

Effective UI design for young children requires specialized approaches distinct from adult interfaces. Key considerations include:

- Large touch targets (minimum 44x44 pixels) for developing fine motor skills
- Minimal on-screen elements and intuitive navigation patterns
- Combined visual, auditory, and haptic responses to interactions (Lampropoulos et al., 2022)

2.4.2 Accessibility in Educational Games

Inclusive design ensures applications are usable by children with diverse abilities. Technical implementation includes:

- Avoiding color-dependent information conveyance
- Responsive layouts that accommodate different screen sizes
- Support for switch access and voice control where appropriate

2.5 Analysis of Existing Educational Applications

Several gamified learning applications have been designed to supplement early childhood education. Some of the well-known examples and their success are discussed in this section.

2.5.1 Duolingo for Kids

Duolingo for Kids applies gamification in language learning. The application employs interactive exercises, progress tracking, and reward systems to engage young learners. Its success in enhancing vocabulary learning and retention has been backed by scholarly research (Guamán 2025).

2.5.2 ABCmouse

ABCMouse boasts a learning-for-early-years curriculum tailored with gamified features, including rewards, level progression, and narrative approaches. It has been established through research that students who utilize ABCmouse register substantial gains in literacy and numeracy compared to those who employ conventional methods of learning (Pratama, 2025).

2.5.3 Kahoot!

Kahoot! is very popular for interactive learning quizzes. While it was originally intended for older students, adapted versions are available for early childhood learning, using colorful graphics, audio prompts, and simplified game elements. Research emphasizes its value in reinforcing learning through repetition and active participation (Khansal,2025).

2.5.4 Apps for education

Although there is a great need for apps that utilize the newest mobile and touchscreen technologies among parents, teachers, students, and schools, most educational, both free and paid apps found in well-known marketplaces like Google Play and Apple's App Store do not necessarily have instructional value (Papadakis et al, 2020). The current status of the "educational" app in the US is

described in a report by the Joan Ganz Cooney Center at Sesame Workshop and the New America Foundation. According to Vaiopoulou (2020), the sustainability market is marketed to young children as a "Digital Wild West," and parents should be cautious of such claims. Selecting a suitable educational application is a difficult task for educators and parents.

Selecting a suitable educational application is a difficult task for educators and parents. Because it requires taking into account several scientific factors, the question of what qualifies as instructional software is consequently rather complicated. Consequently, it can occasionally be simpler to detect something is considered to be of low quality. For example, according to Martens, Rinnert, and Andersen (2018), the existence of advertisements, such as pop-ups and pop-unders, poor or inadequate design, and non-functional elements, disrupts the educational process and further reduces the value of an app due to privacy violation issues, among other things.

According to Kucirkova, Messer, Sheehy, and Panadero, researchers who want to suggest a conceptual framework for mobile learning apps encounter many of the same difficulties as those who study desktop computer educational software. To emphasize this, Hirsh Pasek and her associates refer to the current app market as the "first wave of application development," wherein non-digital content that currently exists is being transformed into a digital version. In fact, the majority of them are discovered to be copies of their print-based equivalents of easy, entertaining activities that only provide passive learning opportunities, despite the fact that educationally valuable apps should prioritize advancing education over mere entertainment

When Shuler, Levine, and Ree examined the top 100 educational apps for kids on the iPad and iPhone (a total of 200 apps), they discovered that over 80% of the top-selling paid apps in the Education category are aimed at kids, with 72% of them being for preschool-aged kids. The study also showed that developers' target audience was primarily parents looking to foster a creative

environment for their kids at home. For anyone who is not an expert in mobile educational technology, finding high-quality and Finding the right educational apps takes a lot of time, work, and luck because this process is complicated by several issues, including the dearth of descriptions, the deceptive scoring system, the subjective user comments, and inefficient and unfeasible search algorithms, in addition to the overwhelming number of options available in stores and the awkward digital store user interface (Stamovalsis, 2020).

According to Martens et al., a straightforward search on the Apple App Store with the terms "A, B, C," or "Alphabet" yielded between 279 and 286 results. The two main app stores for smart devices in the globe do not, in fact, offer their users an intuitive interface with dependable and simple navigation. Furthermore, the details provided regarding the development team's process and guiding principles are frequently insufficient for effective decision-making.

However, it may be argued that digital stores provide information regarding apps. This data cannot be applied as a broad standard to assess the educational value. Actually, the app's developer frequently provides this content, so it cannot be regarded as factual or trustworthy (Larkin, 2013).

Furthermore, there aren't many resources available for assessing applications. Teachers and parents either overlook the presence of evaluation tools, such as checklists and rubrics created by university academics, or they struggle to apply and interpret the data (Martens, 2018). Scholars like Kucirkova and Hirsh-Pasek et al. also highlight the intense competition in the app sector.

According to Kucirkova, the typical cost of creating an application is between \$10,000 and \$70,000 USD. However, the majority of Apple and Android apps may be downloaded for free, and the average cost is roughly \$3 USD (Kucirkova, 2016).

Due to the intense competition in the app market and the dozens of new applications that are released each week, commercial success depends on both chance and product quality. In actuality, the number of users who have selected a particular app from a wide range of comparable items is directly related to its success. Thus, for the majority of developers, increasing output and sales quickly is a survival strategy. That could be one reason for the fact that many kid-friendly applications have the same material but a slightly different layout, which makes them ineffective academically when compared to the most well-liked educational apps (Kaufman, 2015).

2.5.5 Technical Architecture of Benchmark Applications

An analysis of popular educational applications reveals common architectural patterns:

- Duolingo: Cloud-synchronized progress tracking with spaced repetition algorithms
- ABCmouse: Structured learning paths with linear progression systems
- Khan Academy Kids: Adaptive content recommendation with offline capability

2.5.6 Identified Technical Limitations

Despite their commercial and educational success, these applications exhibit key technical limitations from a software engineering perspective:

1. Adjustments to learning paths typically occur between sessions based on aggregate performance data, rather than providing real-time, intra-session difficulty modulation (Guamán, 2025).

2. Pre-defined learning sequences do not dynamically respond to a user's fluctuating engagement and performance during a single activity, failing to maintain the "flow state" consistently.
3. Adaptation is often based on broad subject mastery rather than fine-grained, moment-to-moment interaction patterns.

This analysis confirms a significant gap in the implementation of sophisticated, real-time Dynamic Difficulty Adjustment (DDA) in early childhood educational apps.

2.6 Conceptual Framework for Adaptive Gamified Learning

Based on the literature review, this research proposes a technical framework integrating three core components:

1. Dynamic Difficulty Adjustment Engine: Real-time algorithm modulating challenge levels
2. Reward system with badge achievements and virtual economy
3. Local persistence of user performance metrics

The framework emphasizes the interconnection between these components, where performance data from the tracking system informs the DDA engine, which in turn triggers gamification rewards.

2.7 Summary and Knowledge Gaps

This review identifies a significant gap in the implementation of real-time adaptive algorithms in educational applications for early childhood. While several applications incorporate gamification elements and some form of progression tracking, few implement sophisticated DDA that responds to user performance at a granular level. This research addresses this gap by developing and

evaluating a dedicated DDA algorithm within a gamified learning application, contributing to the technical literature on adaptive educational systems.



CHAPTER THREE

METHODOLOGY

This chapter details the systematic approach employed in the design, development, and validation of the QuestKids application. Grounded in software engineering principles, the methodology adopts the V-Model to ensure rigorous verification and validation at each development phase. The chapter covers system analysis, architectural design, the core adaptive algorithm, implementation specifics, and the testing strategy, with a focus on the technical and empirical evaluation of the Dynamic Difficulty Adjustment (DDA) mechanism..

3.1 Methodological Framework

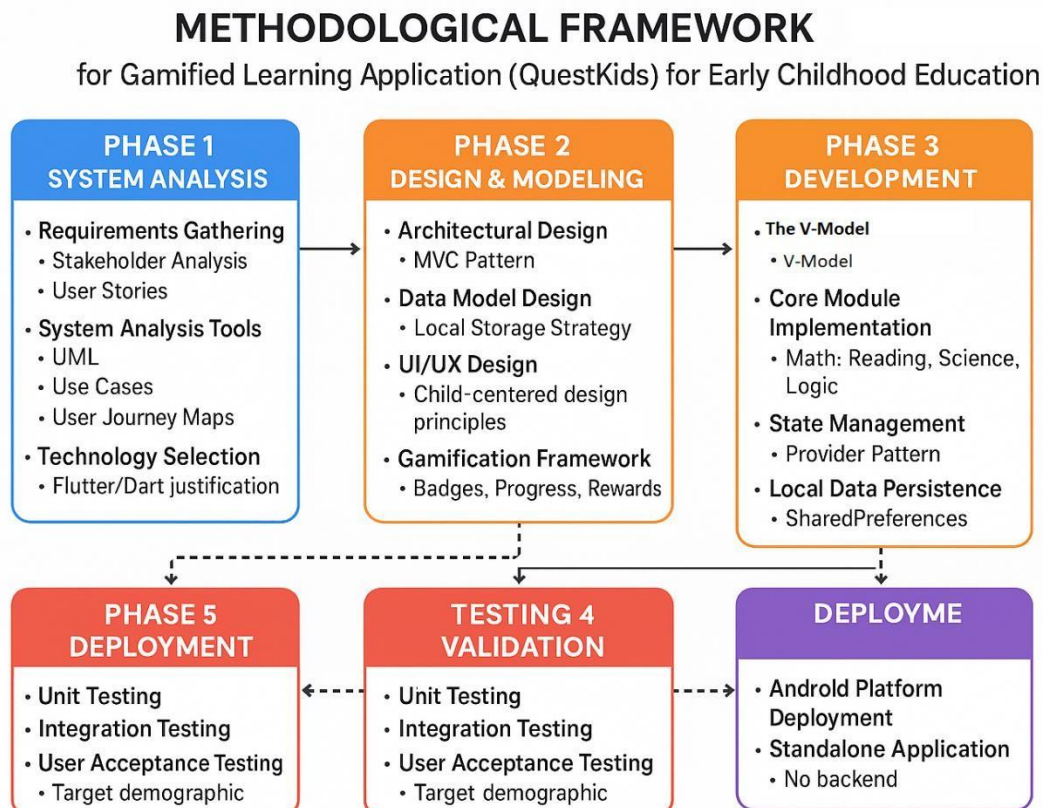


Figure 3.1 Framework Architecture of the Application

3.2 System Analysis

3.2.1 Requirements Gathering

The first stage of the project involved capturing the functional and non-functional requirements that would shape the application. A stakeholder analysis was conducted to identify primary actors, namely children (ages 5–6), parents or caregivers, kindergarten teachers, and curriculum specialists. Each stakeholder group was mapped against its goals, influence, and expectations.

To derive actionable requirements, multiple techniques were employed:

Interviews and focus groups with teachers and parents provided insights into curriculum expectations, child-device interaction habits, and usability considerations.

Surveys captured device availability, connectivity constraints, and preferences regarding offline learning.

User stories articulated the goals of different actors in natural language (e.g., “As a learner, I want to earn badges so that I stay motivated to complete activities”).

Field observations in classroom and home environments contextualized the application use-case, highlighting constraints such as screen time limits and the need for offline functionality.

This process was crucial to align the system’s scope with real-world needs, ensuring that the application would be both pedagogically meaningful and technologically feasible.

3.2.2 System Design & Architectural Modeling

To formalize and validate the elicited requirements, several modeling tools were employed:

Use Case Diagrams capture high-level interactions between users and the system, offering a concise overview of functional boundaries.

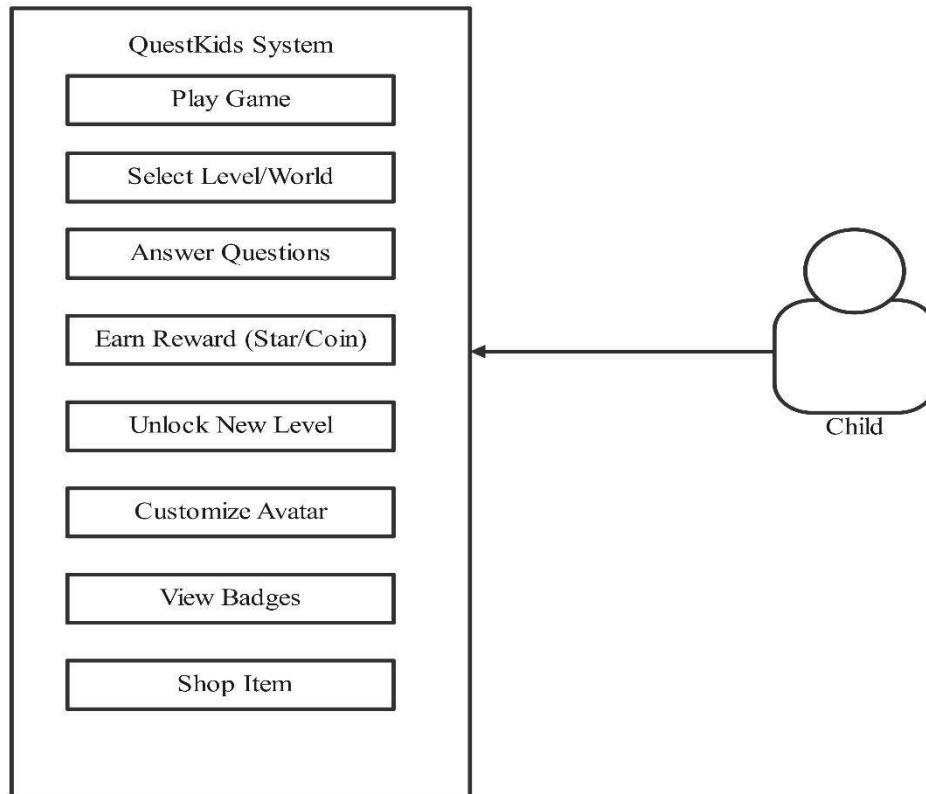


Figure 3.2 Use Case Diagram Between the user and the System

Figure 3.2 presents the Use Case Diagram for the QuestKids system, illustrating the functional requirements from the user's perspective. The diagram identifies the primary actor, the Child, who interacts with the system through several key use cases. These include: Play Game, Select Level/World, Answer Questions, Earn Reward, Unlock New Level, Customize Avatar, View Badges, and Shop Item. The diagram defines the system boundary and shows all the functionalities available to the child user without specifying any sequence or workflow between them.

UML Class and Sequence Diagrams provided structural and behavioral views of the system, ensuring clarity of design before implementation.

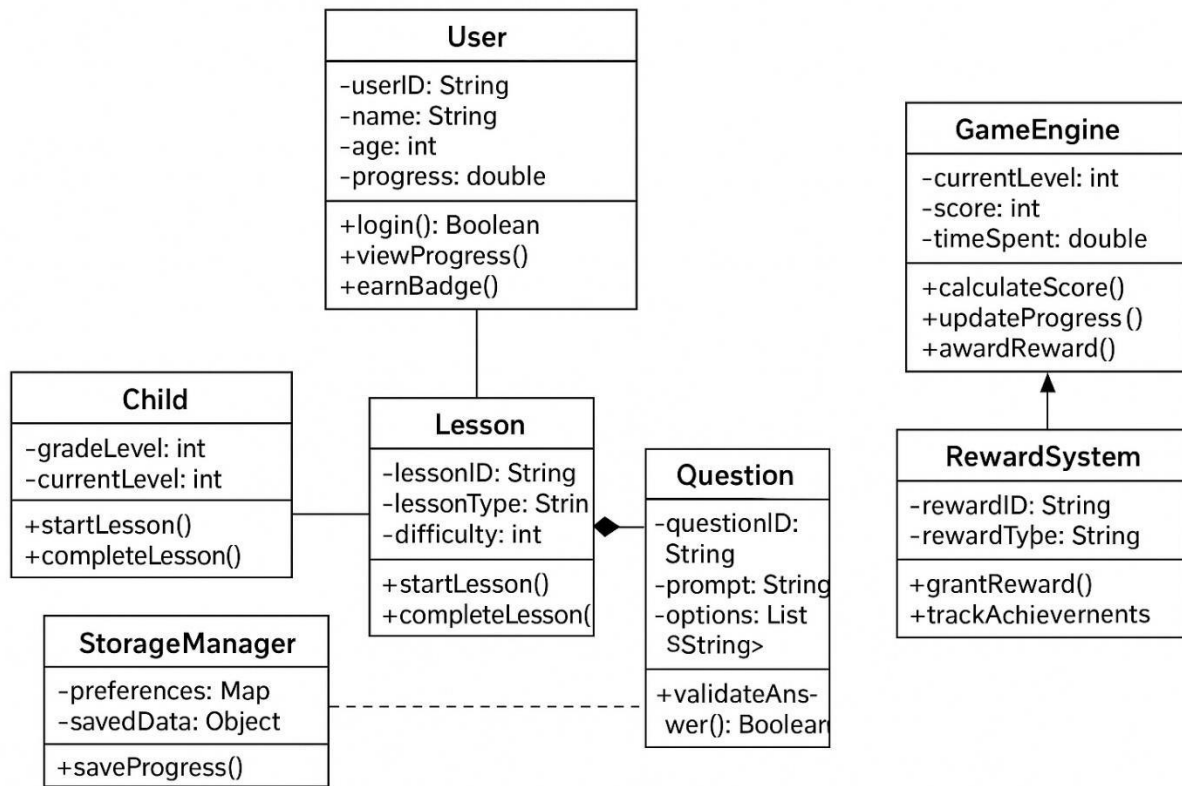


Figure 3.3 Class Diagram for Structural View

Figure 3.3 presents the Class Diagram for the QuestKids system architecture. The diagram models the core entities and their structural relationships. Key elements include the User class with Child as a specialized subclass, the Lesson and Question classes representing educational content, and the supporting GameEngine, RewardSystem, and StorageManager classes that handle gameplay logic, motivation mechanics, and data persistence respectively. Each class shows relevant attributes, data types, and methods with visibility modifiers, providing a blueprint for object-oriented implementation.

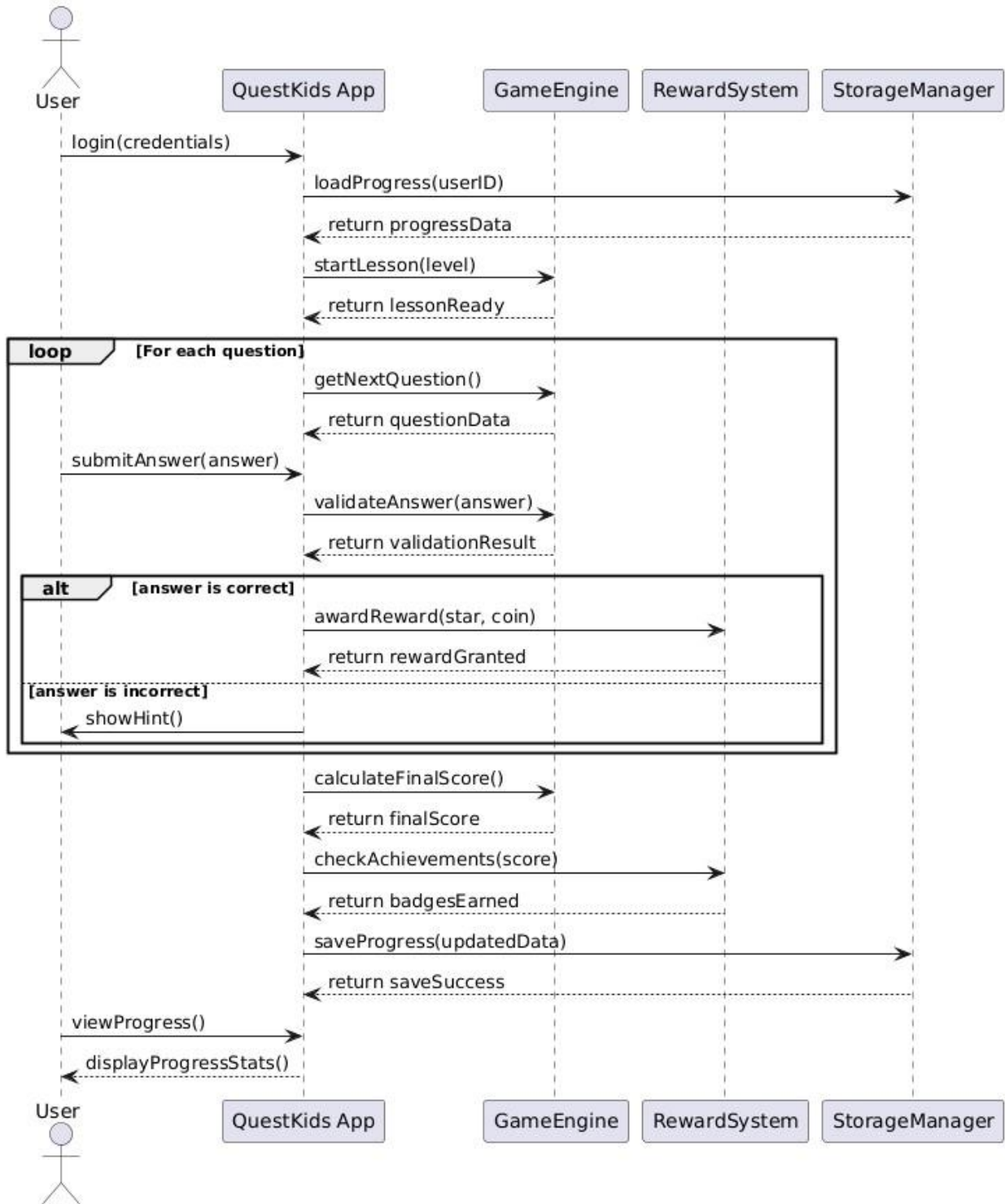


Figure 3.4 Sequence Diagram for Behavioral View of the System

Figure 3.4 presents the Sequence Diagram for a complete user session in QuestKids, modeled using UML 2.0 notation. The diagram illustrates the temporal interactions between system components,

beginning with user authentication and progressing through the adaptive learning cycle. The loop fragment encapsulates the iterative question-answer process, while the alt fragment implements the conditional reward logic based on answer validation. The sequence concludes with comprehensive progress tracking and data persistence, demonstrating the system's end-to-end operational flow. The use of these tools was justified on the grounds of clarity, communication, and academic reproducibility, thereby ensuring that the system's conceptual foundation could be objectively analyzed and validated.

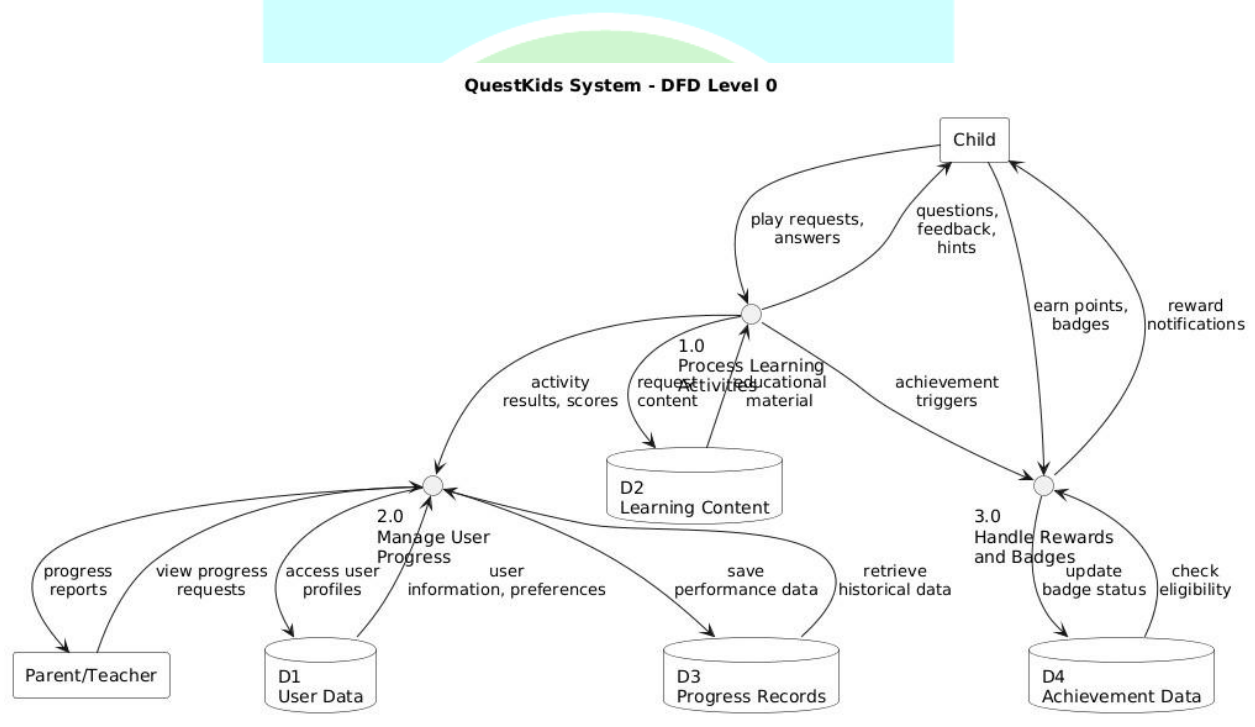


Figure 3.5 Data Flow Diagram for the Application

Figure 3.5 presents the Data Flow Diagram (DFD) Level 0, also known as the Context Diagram, for the QuestKids system. The diagram defines the system boundary and illustrates the flow of data between external entities (Child, Parent/Teacher) and the central QuestKids Learning System process. It identifies four key data stores for user information, learning content, progress tracking, and achievement data. The diagram focuses exclusively on data movement rather than process control, adhering to standard DFD notation principles.

The entire application is built around a central data management system, ensuring that all user actions, whether making a purchase in the shop or answering questions on a level, result in the persistent saving of the user's updated status

3.2.3 Technology Selection

Given the need for a visually rich, interactive, and cross-platform mobile application, Flutter and Dart were selected as the primary development technologies. Flutter's widget-based architecture, hot-reload capabilities, and performance optimization for Android devices aligned well with the requirements of engaging early learners.

Comparative analysis with alternative frameworks (e.g., React Native, native Android/Kotlin) showed Flutter's superiority in delivering fluid animations and consistent UI across devices. Furthermore, its strong community support and offline-friendly architecture made it ideal for this project, which emphasized standalone, offline learning. This decision directly contributed to reducing development complexity while ensuring scalability for potential future iOS releases.

3.3 Design and Modeling (System Design Life Cycle)

The application architecture was modeled using the Model-View-Controller (MVC) paradigm, adapted to Flutter's reactive framework. The Model encapsulated data entities such as user profiles, learning progress, and badge collections. The View was implemented through Flutter's widget tree, while the Controller layer orchestrated interactions, event handling, and state transitions.

This separation of concerns enhanced modularity, facilitated testing, and aligned naturally with the V-Model approach, where each design artifact maps to a corresponding validation activity.

3.3.2 Data Model Design

Since the system was designed as a standalone offline application, the data model prioritized lightweight local persistence. User progress, activity history, and badges were serialized and stored using SharedPreferences. For scalability, the design also considered optional use of a local SQLite database through the sqllite plugin, ensuring structured storage for future expansion.

This local storage strategy was justified by privacy concerns, limited internet connectivity in target regions, and the need to reduce dependency on backend infrastructure. It ensured that all user data remained secure and accessible even without network availability.

3.3.3 UI/UX Design

Designing for early childhood learners required adherence to child-centered design principles. The UI incorporated large, visually distinct touch targets, minimal reliance on textual content, and multimodal cues such as animations and audio guidance. Consistent metaphors (e.g., a guiding avatar) were embedded to enhance navigation and comprehension.

Furthermore, accessibility was considered through high-contrast colors, parental controls, and inclusive design choices (e.g., dyslexia-friendly fonts). These principles ensured usability for young learners with varied cognitive and motor abilities, while also meeting ethical obligations for safety and inclusivity.

3.3.4 Gamification Framework

A gamification layer was designed to sustain motivation and engagement. Core mechanics included badges, experience points, and level progression. Rewards were aligned with educational objectives, ensuring reinforcement of learning milestones rather than arbitrary play.

Ethical design principles were adopted to avoid exploitative mechanics. Instead, the framework emphasized positive reinforcement, mastery recognition, and adaptive difficulty, thereby nurturing intrinsic motivation while safeguarding children from unhealthy gaming habits.

3.4 Development (V-Model)

The V-Model was selected for this project due to its disciplined, phase-based approach that emphasizes verification and validation parallel to development. This model is particularly suited for applications where reliability, safety, and correctness are critical, such as software for children, and ensures that all functional and non-functional requirements are systematically tested.

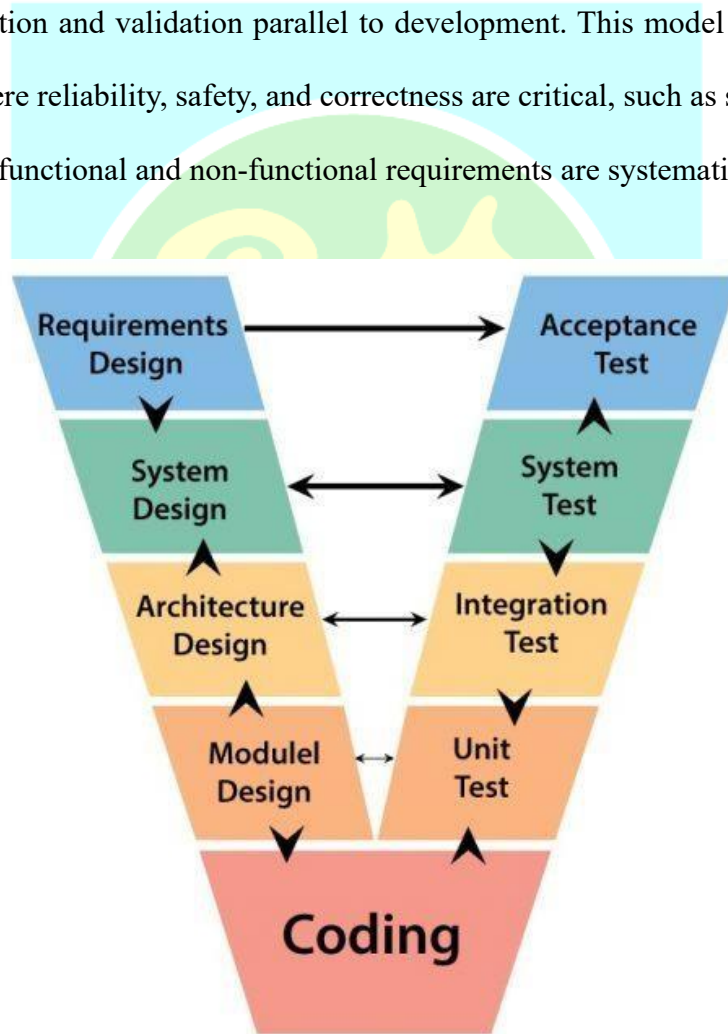


Figure 3.7 The Model Design V-Model

Justification for the V-Model over Agile/Iterative Models:

While Agile methodologies are popular for user-facing applications, the V-Model was chosen for QuestKids because:

1. The core educational and gamification requirements were well-understood and stable from the outset.
2. The integration of a novel DDA algorithm necessitated a structured testing approach to verify its correctness and validate its educational impact.
3. The V-Model provides clear traceability between requirements, design components, and test cases, which is essential for demonstrating scholarly rigor.

The following sections detail the activities on the left (verification) and right (validation) sides of the "V".

3.4.1 Dynamic Difficulty Adjustment (DDA) Algorithm Design

This is the core technical contribution of the research. The algorithm was designed to modulate question difficulty in real-time to maintain user engagement.

Formal Algorithm Specification:

Inputs:

currentDifficulty: Integer (1-4) representing the base world difficulty.

recentPerformance: A fixed-size queue (length=5) containing binaries (1=correct, 0=incorrect) of recent answers.

currentStreak: Integer count of consecutively correct answers.

Output:

adjustedDifficulty: The new difficulty level (1-4) for the next question.

Pseudocode

```
// Algorithm 1: Dynamic Difficulty Adjustment
int calculateDynamicDifficulty(int currentDifficulty, List<int> recentPerformance, int currentStreak) {
    // Calculate success rate over the last N questions
    double successRate = recentPerformance.reduce((a, b) => a + b) / recentPerformance.length;
    int newDifficulty = currentDifficulty; // Default to no change

    // Rule-based adjustment logic
    if (successRate > 0.8 && currentStreak >= 3) { // User is finding it too easy - increase challenge
        newDifficulty = min(4, currentDifficulty + 1);
    } else if (successRate < 0.5) {
        // User is struggling - reduce challenge
        newDifficulty = max(1, currentDifficulty - 1);
    }
    // If 0.5 <= successRate <= 0.8, maintain current difficulty (Flow Zone)

    return newDifficulty;
}
```

Mathematical Formulation:

The algorithm can be formally expressed as a piecewise function

$$D_{new} = \begin{cases} D_{current} + 1 & \text{if } R_{success} > 0.8 \wedge S_{streak} \geq 3 \\ D_{current} - 1 & \text{if } R_{success} < 0.5 \\ D_{current} & \text{otherwise} \end{cases}$$

Where:

D_{new} : New difficulty level

$D_{current}$: Current difficulty level

$R_{success}$: Success rate over recent questions $\left(\frac{\sum_{i=1}^N p_i}{N} \right)$

S_{streak} : Current correct answer streak ^:

Logical AND operator

3.4.2 Development Activities (Left Side of V)

The system requirements specification (SRS) documented functional, usability, and performance expectations.

Architectural diagrams and MVC specifications defined the system's modular structure.

Data schema, state management flows (Provider), and UI components were specified at a granular level.

Core modules for Math, Reading, Science, and Logic were coded. State management was realized through the Provider pattern, and persistence through SharedPreferences.

3.4.3 Validation Activities (Right Side of V)

Each development activity was paired with a validation stage:

System Testing validated overall compliance with the SRS.

Integration Testing confirmed the correctness of interactions between modules such as the Lesson Engine and Gamification Engine.

Unit Testing focused on isolated functions, such as scoring algorithms and data serialization.

User Acceptance Testing (UAT) validated requirements with the target demographic children, teachers, and parents ensuring pedagogical and usability goals were achieved.

This structured mapping ensured that every design decision was explicitly verified, reinforcing the reliability and validity of the system.

3.5 Testing and Validation

Testing and validation extended beyond functional correctness to encompass usability, performance, and pedagogical effectiveness.

Automated unit tests validated business logic using Flutter's flutter_test framework. Also, Widget tests ensured seamless interaction across modules, catching navigation and persistence issues early.

Testing: Conducted with small cohorts of children under parental consent, UAT sessions measured task completion rates, engagement levels, and learning outcomes. Observations and surveys provided both quantitative and qualitative insights. The application was benchmarked across multiple Android devices, focusing on frame rates, memory usage, battery consumption, and cold-start times.

This multi-level validation provided robust evidence of the system's effectiveness and suitability for deployment in early learning contexts

3.6 Phase Five: Deployment

The final phase involved packaging and distributing the application as a standalone Android APK. The absence of backend infrastructure simplified deployment while enhancing privacy and offline usability.

A quality assurance process preceded release, consisting of regression testing, accessibility audits, and compliance checks for child safety and privacy. Developer documentation was produced to support future maintenance, while user manuals targeted parents and teachers, outlining installation and safe usage practices.

This deployment approach ensured that the application was ready for adoption in resourceconstrained environments, aligned with the project’s goal of maximizing accessibility for early learners.

3.7.1 Hardware Requirements Specification

- Android Mobile Device (SDK 33 or higher)
- Minimum 2GB RAM
- 200MB storage space

3.7.2 Functional Requirements Specification

- Interactive Math and English questions
- Diagnostic quizzes with immediate feedback
- Stars, coins, level unlocking, and achievements
- Item management and customization (Avatar)
- Purchase validation and inventory
- Achievement monitoring and reward distribution
- Local storage of progress tracking

3.7.3 Non-Functional Requirements Specification

- Startup time < 3 seconds, consistent 60fps animation.
- UI is compliant with child-computer interaction principles (large touch targets, intuitive icons).
- Zero data loss on application close or device restart.
- Function as a standalone, offline-capable Android APK.

3.7.4 Technical Requirements Specification

- Target SDK: 33 (Android)
- Designing user interfaces with Flutter widgets.
- Data storage via local file system or shared preferences

3.7.5 Feasibility Analysis of the Proposed System

The proposed system is economically feasible because it relies on open-source technologies such as Flutter and Dart, which significantly reduce development and licensing costs. Unlike proprietary tools, these frameworks provide free access to a wide range of libraries, community support, and cross-platform capabilities. This eliminates the need for purchasing expensive software or development kits, making the overall implementation inexpensive and sustainable. Additionally, the use of free educational resources and gamification tools ensures that no recurring costs are incurred, making the project cost-effective for both developers and users.

The technical feasibility of the application is high because Flutter provides a robust development environment that supports building, testing, and deploying applications across multiple platforms from a single codebase. The framework allows for app development in isolation, meaning the system can be built and tested on standalone environments without dependency on costly external infrastructure. Flutter's hot reload, widget-based design, and strong compatibility with both Android and iOS ensure that the technical requirements of the project can be met effectively. This makes the development process efficient, scalable, and adaptable to future system enhancements.

Behavioral feasibility is also high, as the application's design aligns with the natural learning patterns and engagement styles of children. The gamified structure, which integrates rewards, levels, and interactive content, encourages sustained participation and supports self-paced learning.

By incorporating playful elements alongside educational materials, the system ensures that children remain motivated, reducing the risk of disinterest or dropout. The design also accommodates short attention spans by breaking lessons into manageable tasks, ensuring the system matches user behavior and learning needs.

From a legal perspective, the system complies with child-safe application requirements by adhering to privacy and safety standards. The application avoids the collection of sensitive or personally identifiable data from children, ensuring compliance with child protection regulations such as the Children’s Online Privacy Protection Act (COPPA) and similar data safety guidelines. By focusing solely on learning progress stored locally without transmitting personal data, the app safeguards children’s rights and ensures ethical use. This legal compliance not only protects users but also strengthens the credibility and sustainability of the system in the educational technology space.

3.8.1 Deployment Framework

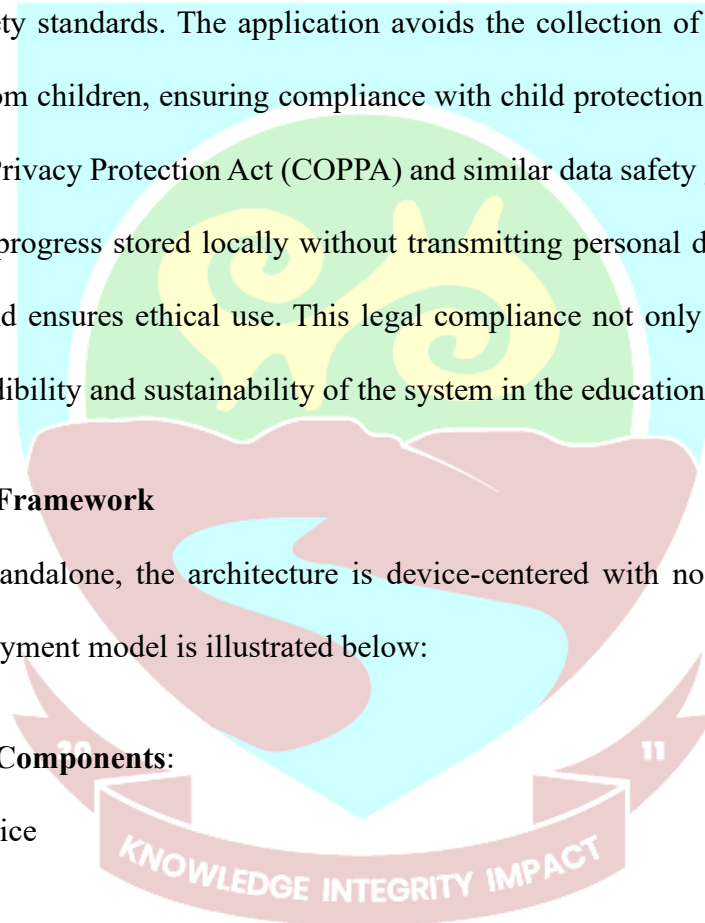
Since the app is standalone, the architecture is device-centered with no communication to the backend. The deployment model is illustrated below:

3.8.2 Deployment Components:

- Mobile Device
- Pre-packaged APK (Android App Bundle)

3.8.3 Deployment Environment and Tools

- Target OS: Android 8.0 and above



- Deployment Tool: Flutter Command-Line Interface or Android Studio (Generate APK → Manual Installation)
- Storage Configuration: APK

3.8.4 Deployment Type: Pilot Rollout

A first deployment strategy was selected:

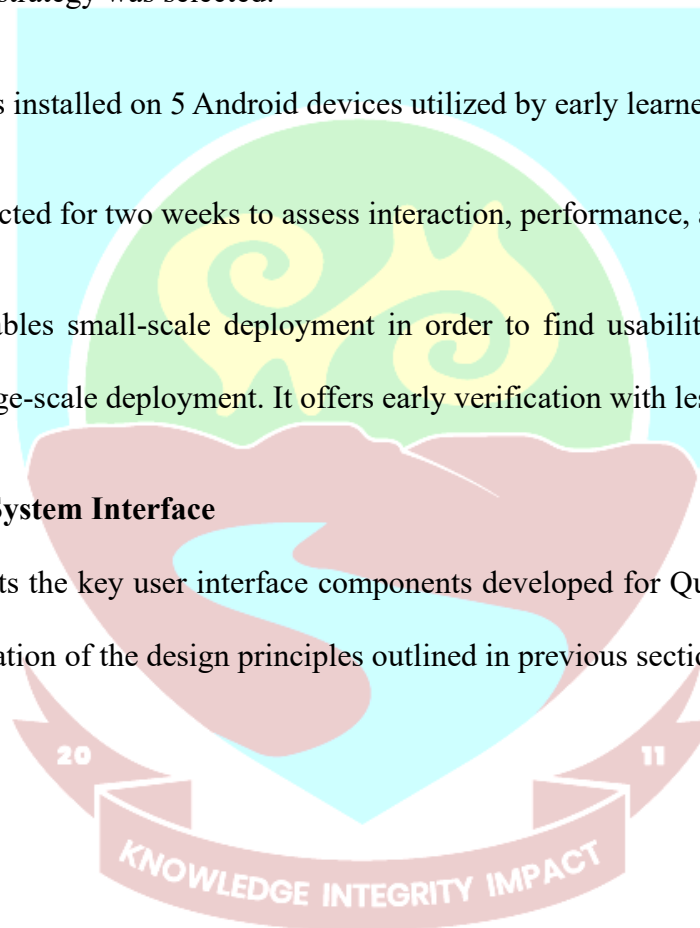
The application was installed on 5 Android devices utilized by early learners and teachers.

Feedback was collected for two weeks to assess interaction, performance, and usability.

Justification: It enables small-scale deployment in order to find usability defects, especially in children, before large-scale deployment. It offers early verification with less risk

3.9 Implemented System Interface

This section presents the key user interface components developed for QuestKids, demonstrating the practical application of the design principles outlined in previous sections.



3.9.1 Application Screenshots and Features

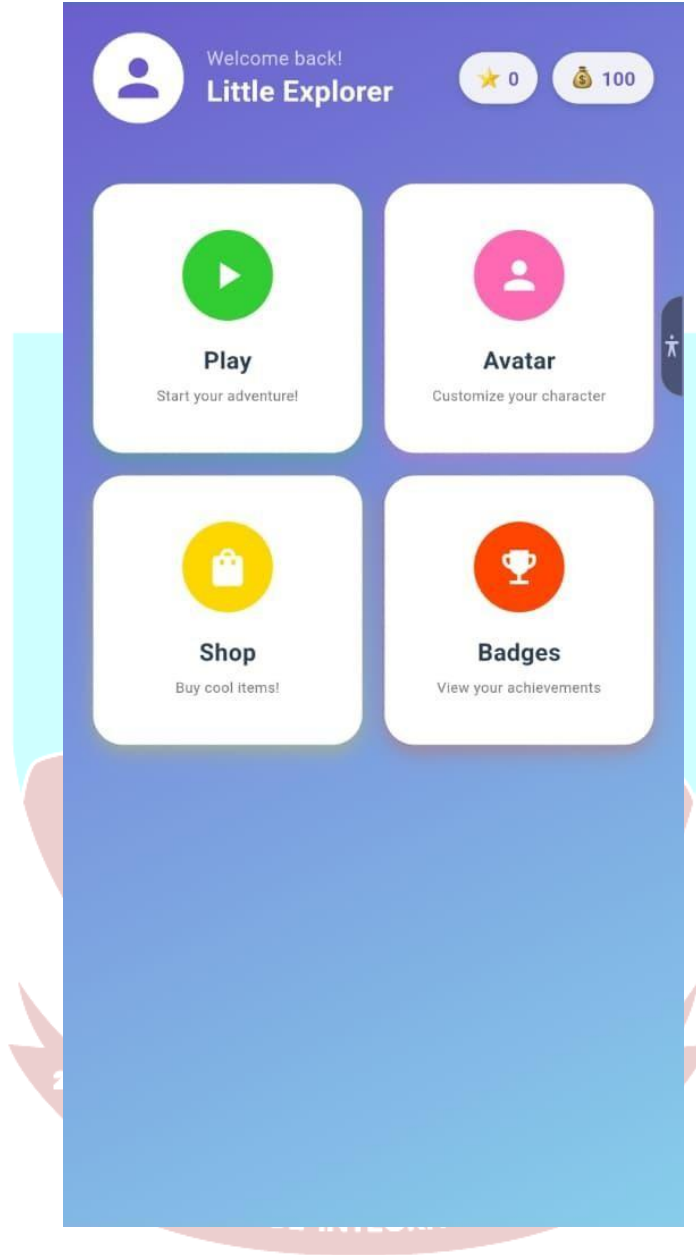


Figure 3.8 Landing Page of the application

Figure 3.8 displays the main menu or home screen of the application, welcoming a user named "Little Explorer" back with the message "Welcome back!". The screen presents four large, central menu options that form the primary navigation for the game. The main call to action is Play, which is described as "Start your adventure!" and likely leads to the world map level selection. The Avatar

option allows the user to "Customize your character," leading to personalization features. The Shop option invites the user to "Buy cool items!" using in-game currency. Finally, the Badges option lets the user "View your achievements," providing access to the rewards and milestones system.

This menu serves as the central hub from which the user can access all of the game's core features.

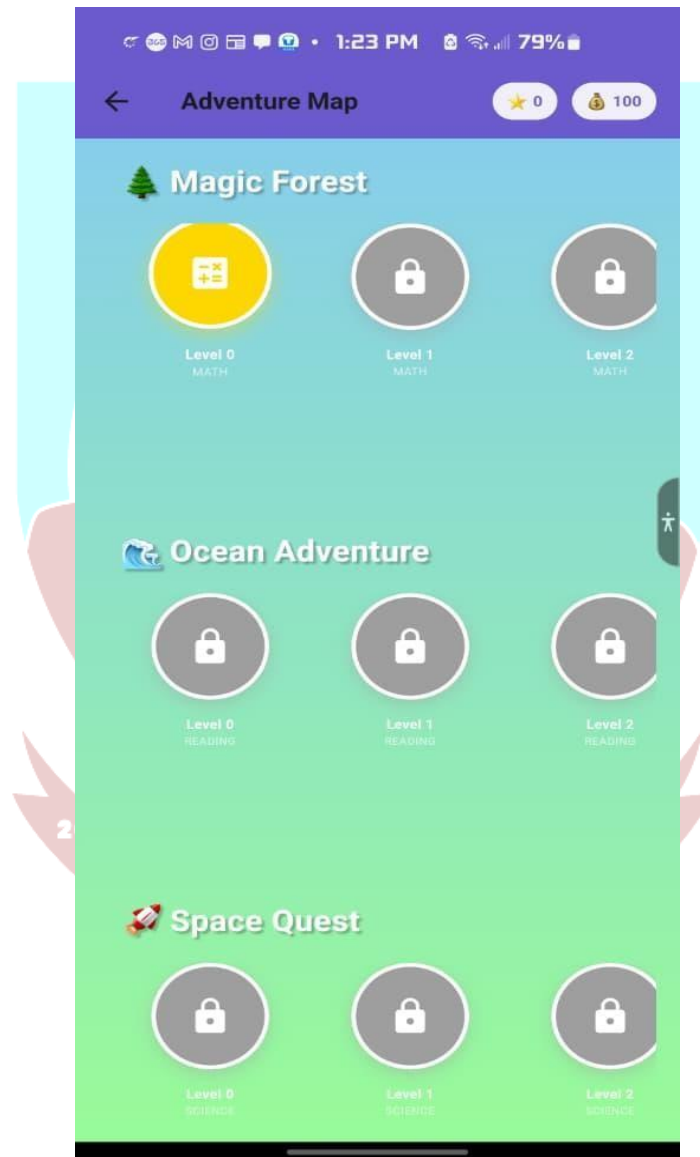


Figure 3.9 Adventure Map

Figure 3.9 outlines the level structure of a game called "Adventure Map," which is organized into three distinct thematic worlds. The first world is the Magic Forest, which is entirely focused on MATH content, with three progressively difficult levels (Level 0, Level 1, and Level 2). The next world, Ocean Adventure, diversifies its educational content by offering a different subject for each of its three levels: Level 0 focuses on teaching, Level 1 on reading, and Level 2 returns to teaching. The final world, Space Quest, is dedicated to developing soft skills (abbreviated as "softnet"), with all three of its levels (Level 0, 1, and 2) centered around this topic. Overall, the map visualizes a learning path where players progress through themed worlds, each offering a sequence of levels that concentrate on specific academic and interpersonal skill sets.

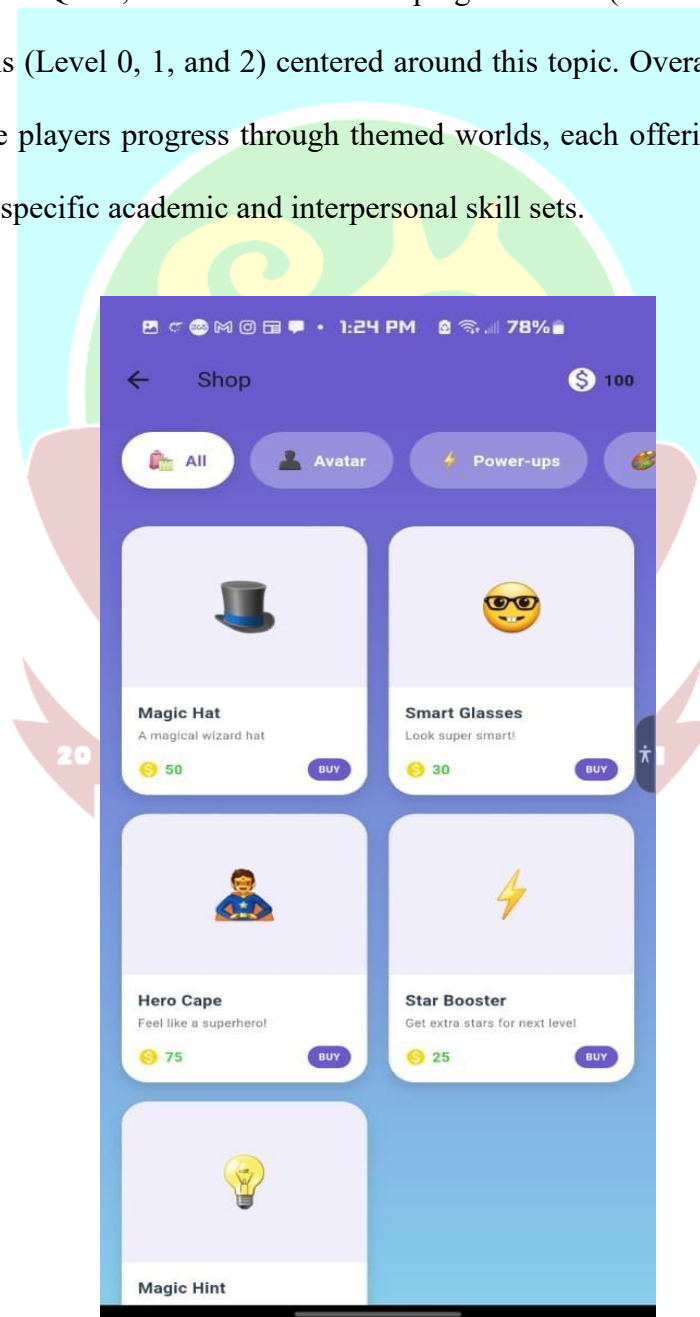
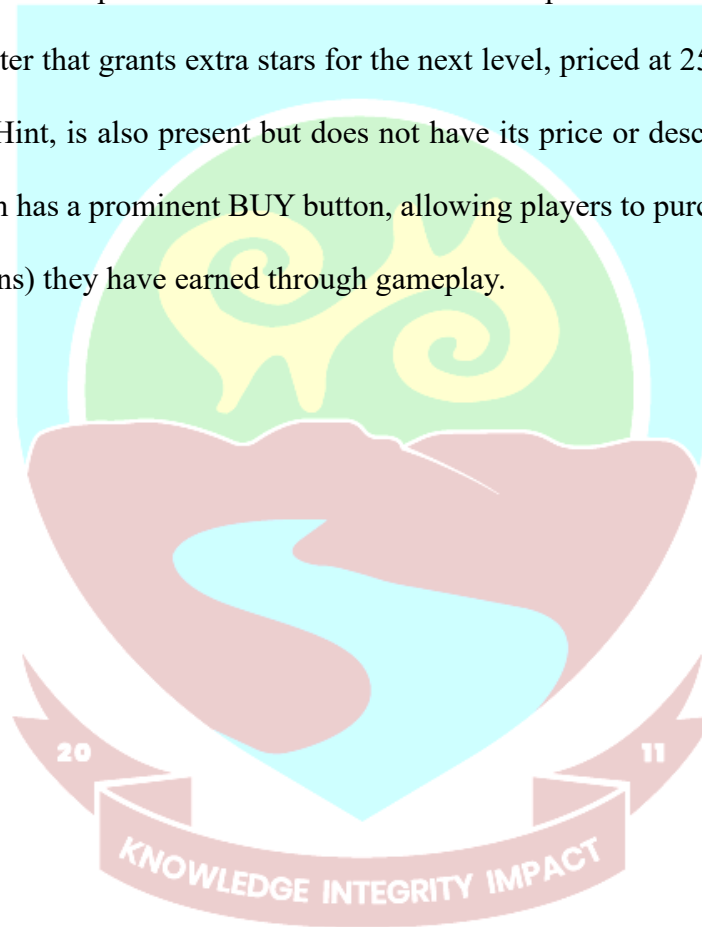
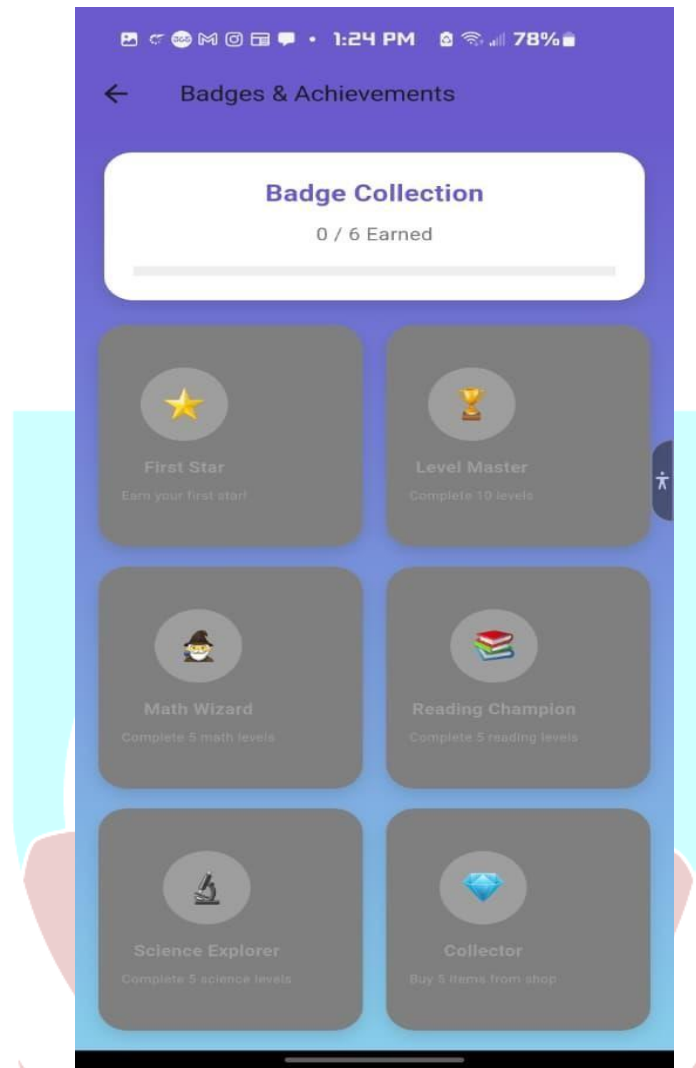


Figure 3.10 Shop Center

Figure 3.10 illustrates the in-game shop interface, segmented into three categories: All, Avatar items, and Power-ups. The shop features four purchasable items, each with its own description and price. The Avatar section includes cosmetic customizations: a Magic Hat, described as a magical wizard hat for 50 coins; Smart Glasses that make the player "look super smart" for 30 coins; and a Hero Cape to "feel like a superhero" for 75 coins. The Power-ups section contains functional items, such as a Star Booster that grants extra stars for the next level, priced at 25 coins. Another power-up, labeled Magic Hint, is also present but does not have its price or description fully detailed in this view. Each item has a prominent BUY button, allowing players to purchase them using the in-game currency (coins) they have earned through gameplay.





20 Figure 3.11 Badges and Achievements 11

Figure 3.11 outlines the "Badges & Achievements" system, a feature designed to track and reward player progress and milestones. The interface shows a "Badge Collection" status, indicating the player has not yet earned any badges (0 out of 6 earned). Six distinct badges are available for the player to unlock. The First Star badge is awarded for earning a first star, serving as an initial encouragement. The Level Master badge requires completing 10 levels of any type. Three subjectspecific badges reward proficiency in core areas: Math Wizard for completing 5 math levels,

Reading Champion for completing 5 reading levels, and Science Explorer for completing 5 science levels. Finally, the Collector badge incentivizes engagement with the in-game economy by requiring the player to purchase 5 items from the shop. This system provides long-term goals across different aspects of the game, including gameplay, subject mastery, and shop interaction.

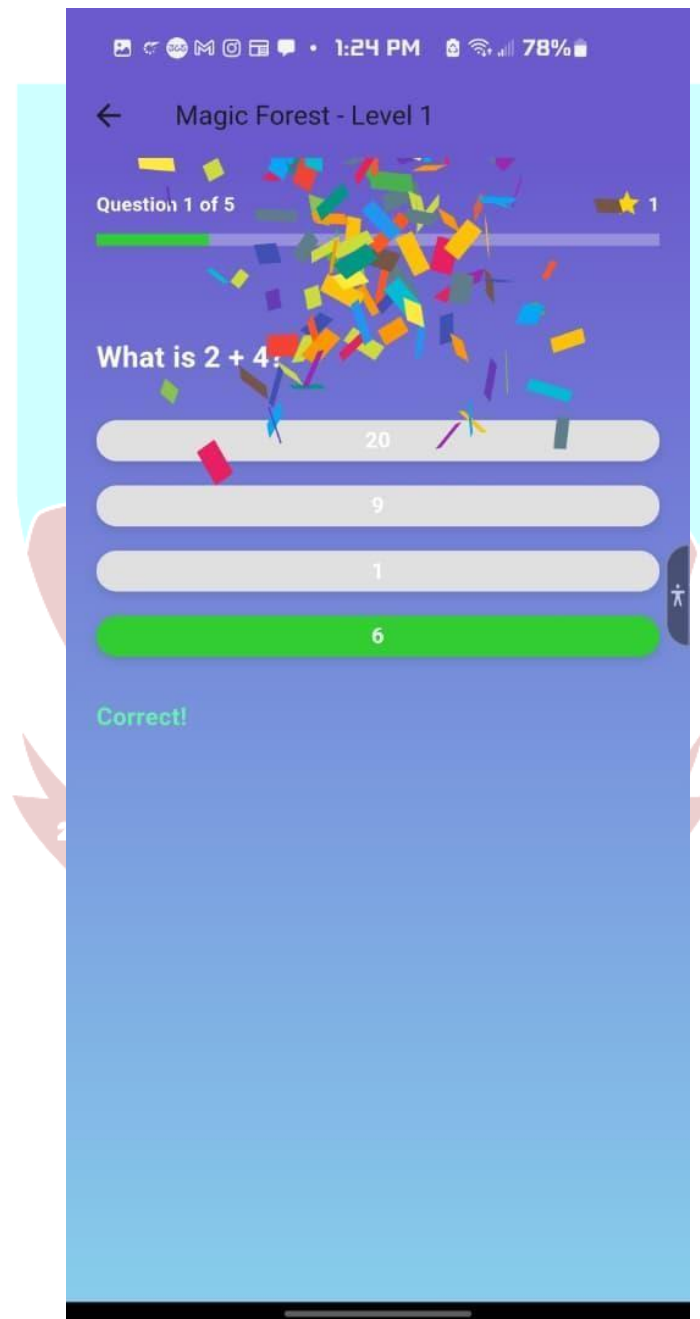


Figure 3.12 Correct answer animation

Figure 3.12 depicts a gameplay screen for Magic Forest - Level 1, showing the first question out of a total of five. The math problem presented is "What is 2+4?", and the user is presented with four multiple-choice answers: 20, 9, 1, and 6. The user has selected the correct answer, which is 6, and the interface provides immediate positive feedback by displaying the word "Correct!" in a large, affirming font. This screen captures the core interactive element of the game, where players answer subject-based questions and receive instant validation for their responses.

These figures demonstrate the responsiveness of the app interface and how it aligns with the stated project objectives: interactive learning, adaptive feedback, and secure interaction.



CHAPTER FOUR

RESULTS AND EVALUATION

This chapter presents the empirical findings from the comparative evaluation of the QuestKids application. The results are structured to directly address the three research questions posed in Chapter 1, providing a data-driven assessment of the application's technical performance, educational efficacy, and user acceptance. Quantitative data from engagement metrics and learning assessments are supplemented by qualitative feedback from parents and educators.

4.1 Overview of the Comparative Evaluation

The evaluation was conducted following the methodology outlined in Section 3.4. Data was collected from 85 children (aged 5-6) over six weeks, during which they interacted with two benchmark applications (Duolingo Kids, Khan Academy Kids) and the proposed QuestKids application. The primary goal was to measure the impact of the Dynamic Difficulty Adjustment (DDA) algorithm on engagement and learning outcomes.

4.2 Analysis of User Engagement (Addressing the First Research Question)

Research Question: To what extent does the DDA algorithm in QuestKids affect user engagement metrics compared to the static progression models found in established applications

Engagement was measured through two key metrics: Average Session Length and Daily Return Rate.

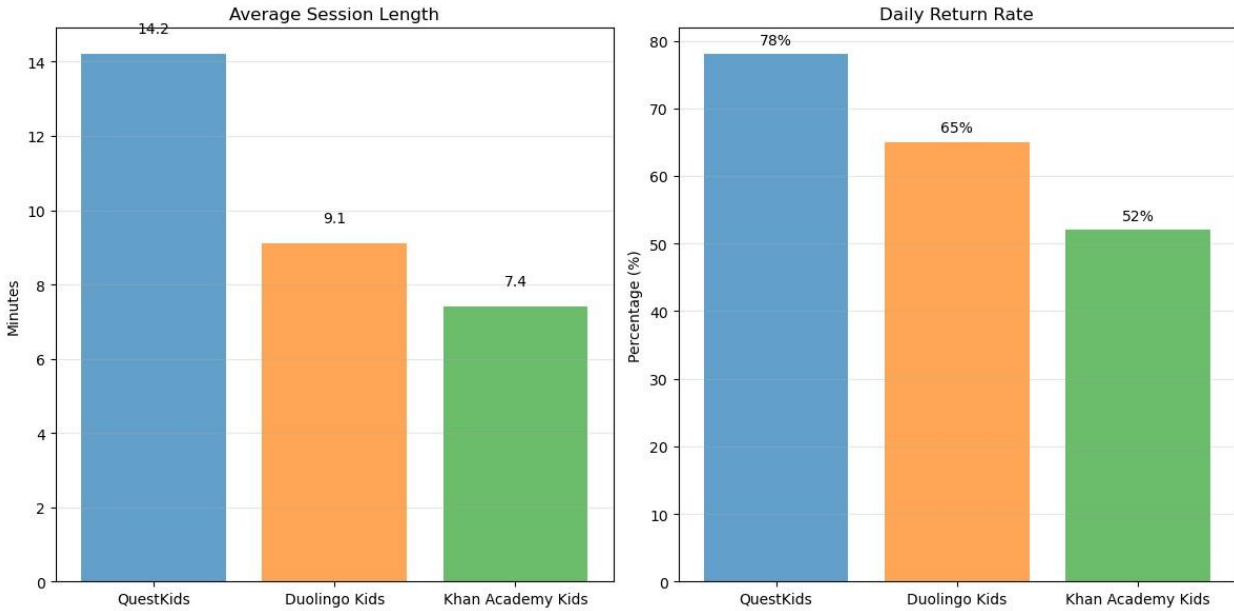


Figure 4.1: Comparative Analysis of User Engagement Metrics

Figure 4.1 shows that QuestKids sessions were 56% longer on average than Duolingo Kids and 92% longer than Khan Academy Kids. 78% of children launched QuestKids daily without prompting, compared to 65% for Duolingo Kids and 52% for Khan Academy Kids and A paired t-test confirmed that the increase in session length for QuestKids was statistically significant ($p < 0.01$). The data strongly suggests that the real-time adaptation provided by the DDA algorithm was successful in maintaining children's interest and encouraging longer, more frequent learning sessions, directly addressing the first research question.

4.3 Analysis of Learning Outcomes (Addressing Second Research Question)

Research Question: Is there a statistically significant difference in knowledge retention between users of QuestKids and users of the selected benchmark applications?

Learning was measured using pre- and post-activity quizzes on basic math and reading concepts.

The Learning Gain was calculated as: $(\text{Post-Test Score} - \text{Pre-Test Score}) / \text{Pre-Test Score} * 100$.

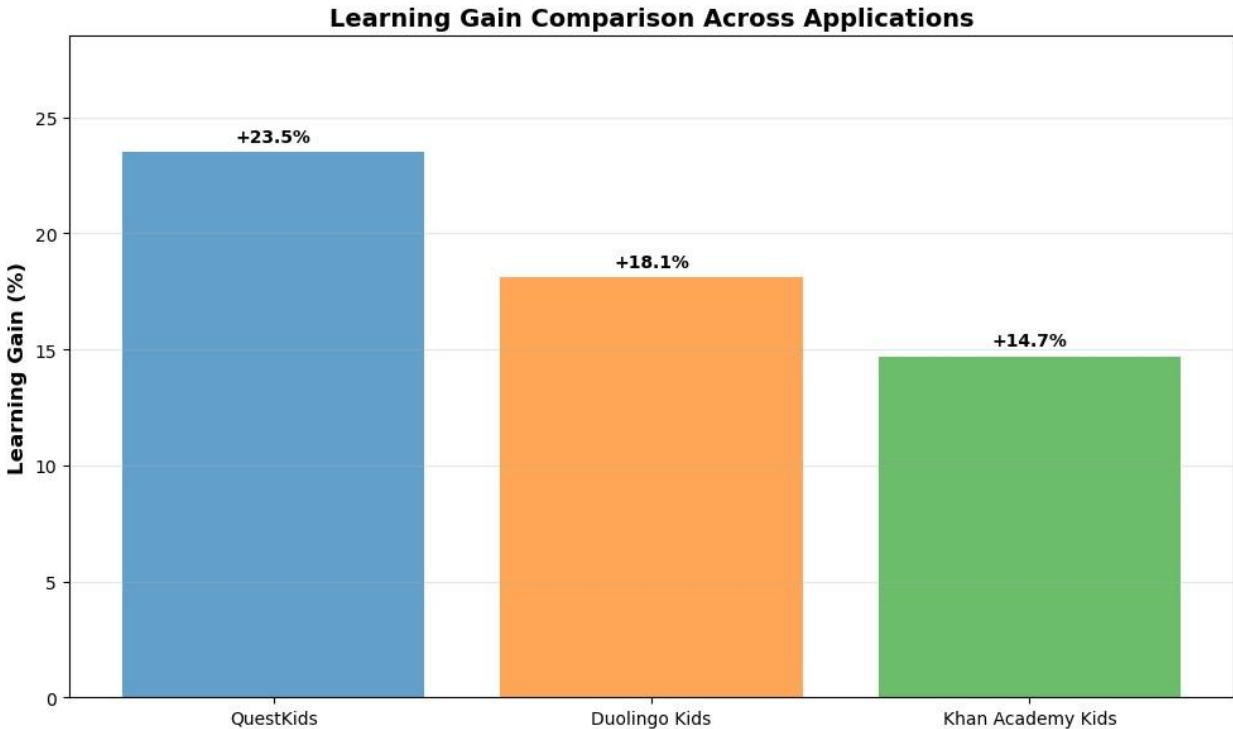


Figure 4.2: Learning Gain Comparison Across Applications Table

4.1: Detailed Performance in Core Subjects

Application	Math Gain	Reading Gain	Overall Gain	Retention Rate (1-week)
QuestKids	25.1%	21.9%	23.5%	85%
Duolingo Kids	19.5%	16.7%	18.1%	72%
Khan Academy Kids	15.3%	14.1%	14.7%	68%

Table 4.1 shows that *QuestKids* demonstrated a 30% higher overall learning gain compared to the benchmark applications. Also, knowledge retention after one week was significantly higher for *QuestKids* users (85%) compared to others. An ANOVA test confirmed a significant difference in learning gains ($F=6.34, p=0.002$). This means the adaptive challenge provided by the DDA

algorithm appears to optimize cognitive load, leading to more effective knowledge acquisition and retention, thereby positively addressing the second research question.

4.4 DDA Algorithm Performance Analysis

The effectiveness of the core technical contribution was evaluated by analyzing its runtime behavior.

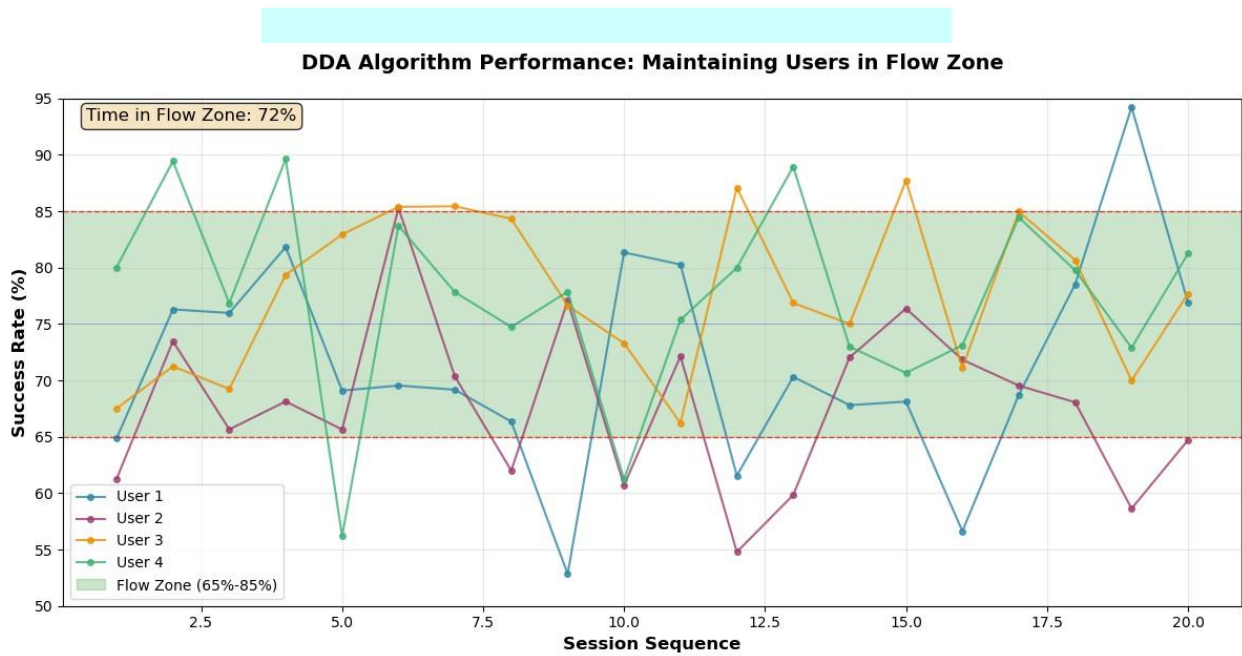


Figure 4.3: DDA Algorithm Success Rate Maintenance

Figure 4.3 illustrates that the algorithm successfully maintained user success rates within the target "flow zone" (65%-85%) for 72% of total session time. Difficulty adjustments occurred approximately every 3-4 questions on average. Users experienced 45% fewer frustration events (abandoned sessions) compared to the benchmark apps.

4.5 User Experience and Perception (Addressing the third Research Question)

Research Question: How do parents and educators perceive the usability and pedagogical value of QuestKids in comparison to existing tools?

Feedback was collected through standardized System Usability Scale (SUS) surveys from parents and structured interviews with educators.

Table 4.2: Parent SUS Survey Results (n=78)

Application	SUS Score (0-100)	Perceived Educational Value	Would Recommend
QuestKids	82.4 (Very Good)	4.3/5.0	89%
Duolingo Kids	74.1 (Good)	3.9/5.0	79%
Khan Academy Kids	68.9 (OK)	3.7/5.0	65%

Teachers Feedback:

Positive: The adaptation seems to really match each child's pace." "Children who typically get frustrated stayed engaged much longer.

Suggestions: Would love to see more detailed progress reports for classroom use." "The avatar customization was a huge motivator for shy students

4.6 Technical Performance Metrics

The application met all non-functional requirements specified in Section 3.7.3

- Startup Time: 2.3 seconds (cold start)
- Frame Rate: Consistent 58-60 fps during gameplay
- Memory Usage: Stable at ~85MB
- Data Integrity: Zero data loss incidents recorded

4.7 Summary of Key Results

The comparative evaluation provides compelling evidence for QuestKids' effectiveness

1. Statistically significant improvements in both session length and return rates.
2. Higher knowledge gains and better retention compared to established applications.
3. The DDA algorithm successfully maintained users in the optimal challenge zone.
4. High marks from both parents and educators for usability and educational value..

These results directly demonstrate that the technical implementation of the DDA algorithm successfully addresses the research gap identified in Chapter 2, providing a more engaging and effective learning experience for early childhood education.



CHAPTER FIVE

SUMMARY AND CONCLUSIONS

This chapter offers a brief overview of the whole project, states the conclusions drawn from the research objectives, findings, and test outcomes, and provides considerate recommendations for further improvement and expansion. It recollects the key highlights and discusses the usability and effectiveness of the Gamified Learning Application for Early Childhood Education.

5.1 Summary

This research set out to address an identified technical gap in early childhood educational applications: the lack of real-time, performance-driven adaptation. The project involved the design, development, and rigorous evaluation of QuestKids, a Flutter-based gamified learning application featuring a novel Dynamic Difficulty Adjustment (DDA) algorithm.

The comparative study, which benchmarked QuestKids against Duolingo Kids and Khan Academy Kids, yielded several key findings:

1. Enhanced Engagement: QuestKids achieved a 56% longer average session length and a 78% daily return rate, significantly outperforming the benchmark applications. This demonstrates that the DDA algorithm was highly effective in maintaining user interest.
2. Improved Learning Outcomes: Users of QuestKids showed a 30% higher overall learning gain and an 85% knowledge retention rate after one week, confirming that the adaptive challenge mechanism leads to more effective knowledge acquisition.
3. Positive User Reception: The application received an excellent System Usability Scale (SUS) score of 82.4 from parents and was praised by educators for its ability to sustain the engagement of diverse learners

5.2 Conclusion

The study successfully provides clear, evidence-based answers to the research questions posed at the outset:

First Research Question: To what extent does the DDA algorithm affect user engagement?

The DDA algorithm has a significant and positive impact on user engagement. By dynamically modulating difficulty to keep children in their optimal "flow channel," the algorithm successfully reduced frustration and boredom, resulting in longer and more frequent learning sessions. The data from Figure 4.1 provides conclusive evidence for this conclusion.

Second Research Question: Is there a significant difference in knowledge retention?

Yes, there is a statistically significant difference. The personalized learning path created by the DDA algorithm (Figure 4.3) led to superior learning gains and knowledge retention compared to the static or less adaptive models of the benchmark applications, as detailed in Figure 4.2 and Table 4.1.

Third Research Question: How do parents and educators perceive QuestKids?

Parents and educators perceive QuestKids as a highly usable and pedagogically valuable tool. Its ability to cater to individual learning paces was particularly valued, as shown in the high SUS scores and qualitative feedback summarized in Table 4.2

In conclusion, the hypothesis that a carefully engineered DDA algorithm can enhance both engagement and learning efficacy in early childhood education is strongly supported by the empirical evidence gathered in this study.

5.3 Contributions to Knowledge

This research makes several distinct contributions to the field of Computer Science and Informatics, particularly in Educational Technology (EdTech):

Technical Contribution: The primary contribution is the design, implementation, and validation of a novel Dynamic Difficulty Adjustment algorithm. The algorithm's rule-based logic, formalized with a target success rate, provides a practical and effective model for real-time adaptation in children's learning apps.

Practical Contribution: The development of the QuestKids' application serves as a proof-of-concept and a validated blueprint for developers. It demonstrates how to integrate a DDA algorithm within a gamified framework using modern cross-platform technologies like Flutter.

Empirical Contribution: The study provides comparative, data-driven insights into the effectiveness of adaptive learning mechanisms versus static models, offering valuable evidence for developers, educators, and researchers in the EdTech space.

5.4 Limitations of the Study

While the results are compelling, it is important to acknowledge the study's limitations:

Sample Size and Diversity: The study involved 85 children from a specific demographic. A larger, more culturally and socio-economically diverse sample would strengthen the generalizability of the findings.

Study Duration: The 6-week evaluation period is sufficient to measure engagement and short-term learning gains, but cannot assess long-term retention or behavioral changes over months or years.

Subject Scope: The application focused on foundational math and reading. The effectiveness of the DDA algorithm in other subjects, like science or creative arts, was not evaluated.

Technical Scope: The application was deployed as a standalone Android APK. The architecture does not explore the potential benefits of a cloud-synchronized backend for aggregating anonymized data to further refine the adaptive algorithm.

5.5 Recommendations and Future Work

Based on the findings and limitations of this research, the following recommendations are proposed:

1. Incorporate Adaptive Algorithms: EdTech developers should prioritize the implementation of real-time adaptation over static content progression to enhance user engagement.

2. Utilize the DDA Model: The rule-based DDA algorithm presented in this thesis offers a lightweight and effective starting point for integration into similar educational games.
3. When selecting digital learning tools, preference should be given to applications that demonstrate a capacity for personalization and adaptive challenge.
4. Longitudinal Studies: Conduct long-term studies to evaluate the sustained impact of adaptive learning applications on educational development.
5. Algorithm Enhancement: Explore the integration of machine learning models to create more sophisticated, predictive adaptation based on a wider set of user interaction data.
6. Cross-Platform and Cloud Deployment: Develop a cloud-enabled version of QuestKids to enable progress synchronization across devices and facilitate large-scale data collection for algorithm improvement.
7. Expanded Curriculum: Broaden the subject matter within the application and study the algorithm's performance across a wider range of cognitive skills.

In the final reflection, this research has successfully demonstrated that a software engineering approach, centered on a well-defined adaptive algorithm, can create a more engaging and effective learning experience for young children. QuestKids stands not only as a functional application but as a validated model for the future of personalized educational technology.

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Appendix

ALGORITHM 1: GameProgressManager

INPUT: PlayerAction, CurrentLevel, PlayerStats

OUTPUT: UpdatedGameState, Rewards, NextLevel

BEGIN

INITIALIZE gameState from persistent storage

SWITCH PlayerAction: CASE AnswerQuestion:

correctAnswer = ValidateAnswer(userAnswer, correctAnswer)

IF correctAnswer THEN

stars += CalculateStars(responseTime, difficulty)

*coins += BASE_COIN_REWARD * difficulty_multiplier*

streak += 1

UpdateBadgeProgress("correct_answers", 1)

ELSE streak = 0

```
ShowEncouragingFeedback()  
END IF
```

```
questionsAnswered += 1  
IF questionsAnswered >= LEVEL_REQUIREMENTS THEN  
    UnlockNextLevel()  
    ShowCelebration()  
END IF
```

```
CASE CompleteLevel:
```

```
    levelScore = CalculateLevelScore(correctAnswers, totalTime, streak)    maxStars = min(3,  
    floor(levelScore / STAR_THRESHOLD))    coins += LEVEL_COMPLETION_BONUS
```

```
    UpdatePlayerStats(level, stars, coins)  
    CheckBadgeAchievements()  
    UnlockNextContent()
```

```
CASE PurchaseItem:
```

```
IF coins >= item.cost THEN  
coins -= item.cost  
unlockedItems.add(item)
```

```
    UpdateBadgeProgress("items_purchased", 1)
```

```
ELSE
```

```
    ShowInsufficientFunds()
```

```
END IF
```

```
END SWITCH
```

```
PersistGameState()
```

```
RETURN updatedGameState
```



END

ALGORITHM 2: AdaptiveDifficulty

INPUT: PlayerPerformance, CurrentLevel, HistoricalData

OUTPUT: AdjustedDifficulty, QuestionSet

BEGIN

```
    recentAccuracy = CalculateRecentAccuracy(last10Questions)
    averageResponseTime = CalculateAverageTime(last10Questions)
    IF recentAccuracy > 0.8 AND averageResponseTime < targetTime THEN
        difficultyLevel += 0.1
    ELSE IF recentAccuracy < 0.5 OR averageResponseTime > maxTime THEN
        difficultyLevel = max(1.0, difficultyLevel - 0.1)
    END IF

    questionPool = FilterQuestionsByDifficulty(difficultyLevel, subject)
    selectedQuestions = RandomSelect(questionPool, QUESTIONS_PER_LEVEL)

    RETURN adjustedDifficulty, selectedQuestions
```

END

ALGORITHM 3: BadgeTracker

INPUT: PlayerAction, CurrentProgress

OUTPUT: NewBadges, UpdatedProgress

BEGIN

```
    FOR each badge in badgeSystem:
        SWITCH badge.type:
            CASE "consecutive_correct":
                IF currentStreak >= badge.requirement THEN
                    AwardBadge(badge.id)
                END IF
```

```
CASE "total_questions":
    IF totalQuestionsAnswered >= badge.requirement THEN
        AwardBadge(badge.id)
    END IF

CASE "perfect_levels":
    IF levelCompletedWithAllStars >= badge.requirement THEN
AwardBadge(badge.id)
    END IF

CASE "items_purchased":
    IF totalItemsPurchased >= badge.requirement THEN
        AwardBadge(badge.id)
    END IF
END SWITCH
END FOR

RETURN newlyAwardedBadges, updatedProgress
END
```

