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Enhancing Diabetes Self-Monitoring via Mobile App: An MVVM and Firebase Approach

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Abstract

Diabetes Mellitus is a chronic metabolic disorder that demands continuous and disciplined self-management to prevent severe systemic complications. Despite its critical importance, patient adherence to regular blood glucose tracking, dietary restrictions, and medication schedules remains low in Indonesia. This study addresses these challenges by developing and evaluating DiabetesKu, a native mobile health application designed to facilitate independent diabetes management. Engineered using Android Studio with the Kotlin programming language, the system implements the Model-View-ViewModel MVVM architecture to decouple business logic from the user interface, while leveraging the Firebase cloud ecosystem for secure, real-time data synchronization and automated reminder deployment. The application integrates core features such as interactive health logging, contextual diabetes education, medication alarms, macronutrient tracking, and direct consultation channels. To evaluate its structural integrity and operational viability, a multi-tiered testing framework was applied. Automated Black Box testing using the Espresso framework across ten critical functional scenarios achieved a 100% success rate, confirming high code stability. Furthermore, field usability evaluations involving active diabetes patients demonstrated an outstanding cumulative satisfaction rate of 91.7%, with users highly praising its clinical usefulness, navigational simplicity, and visual accessibility. The empirical results demonstrate that DiabetesKu is a highly reliable and user-accepted digital health solution capable of promoting patient compliance and reinforcing independent lifestyle control in daily diabetes care.

Keywords: Diabetes Self-Management, Mobile Health, MVVM Architecture, Firebase Backend, Usability Testing, Kotlin.

1. Introduction

Diabetes Mellitus (DM) continues to be a major global health challenge that requires continuous management to prevent severe complications and maintain the patient's quality of life [1]. In managing this chronic condition, patients often face difficulties in tracking blood glucose levels, maintaining strict dietary plans, and executing routine physical activities independently [2] [11]. To address these challenges, the implementation of digital health interventions, particularly through mobile health (mHealth) applications, has emerged as a highly effective preventive solution [3]. Mobile technology offers an accessible, scalable, and personalized platform that empowers patients to conduct self-management dynamically in their daily routines [4].

Several previous studies have explored the development and effectiveness of mobile applications in diabetes care [12]. For instance, a scoping review highlighting that Diabetes Self-Management (DSM) applications significantly assist patients across various regions in managing their condition independently, thereby reducing the direct burden on healthcare systems [5]. Furthermore, research demonstrated that designing blood glucose monitoring applications using Modern Android Development (MAD) tech stackssuch as Kotlin and Jetpack Compose can optimize a multifactorial approach by integrating features like blood sugar charts, activity logs, and automated medical education recommendations [6].

In Indonesia, localization and community-specific deployment have also been widely studied. A study developed the DM Assistant mobile application, which integrates a push-notification reminder system to enhance patient adherence toward the essential pillars of diabetes mellitus management [7]. Additionally, for early intervention, another research introduced an Android-based screening application designed to classify risk levels and deliver structured diabetes education early on within communities [8].

Despite these technological advancements, empirical evidence indicates that more than 70% of diabetes patients in Indonesia still do not monitor their blood glucose levels regularly, and approximately 30% fail to comply with prescribed medical treatments [9]. If left unmanaged, diabetes can trigger severe long-term complications, including cardiovascular diseases, nephropathy, neuropathy, retinopathy, and lower-limb amputations. With over 70% of the Indonesian population currently having access to smartphones [10] which run on the Android operating system mobile applications present an immense, underutilized potential for structural healthcare intervention [13].

This research aims to develop a mobile-based health monitoring application specifically tailored for diabetes patients, named "DiabetesKu". This application is

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engineered using Android Studio with the Kotlin programming language, implementing the Model-View-ViewModel (MVVM) architecture alongside a Firebase backend to ensure robust, scalable, and clean code performance. DiabetesKu is designed to serve as a practical and comprehensive self-management solution, integrating critical features such as visual blood glucose logging, medication tracking with an automated reminder system, deep macronutrient dietary monitoring, and localized medical consultations. Ultimately, this application is expected to significantly enhance patient awareness and treatment compliance, thereby minimizing the risks of severe diabetic complications through structured, independent daily monitoring.

2. Research Method

The software development methodology and problem-solving framework applied in this study are structured systematically to ensure the engineered application aligns with both technical software engineering standards and user clinical self-management requirements. The research initiated with a comprehensive literature study to explore fundamental concepts, medical boundaries for Type 2 diabetes blood glucose levels, and recent advancements in mHealth applications.

This foundational phase included a comparative analysis of existing applications in the market to map out the competitive feature requirements for the proposed system. Following the literature review, a user requirement analysis was conducted through structured surveys and interviews targeting Type 2 diabetes patients with low-to-medium digital literacy. The feedback gathered from this process established critical non-functional parameters, dictating that the application must feature intuitive navigation, high text readability, and an uncomplicated manual logging mechanism since the system relies entirely on user-generated inputs rather than external automated sensors. Next Use Case Diagram on Figure 1.

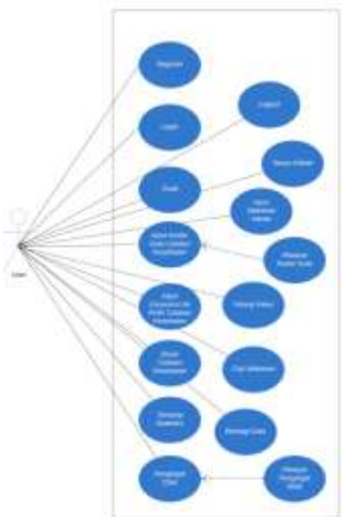

Figure 1. Use Case Diagram

In the system design phase, the operational scope and system boundaries were modeled to visualize the exact interactions between the patient and the system modules. The detailed functional boundaries and user roles established during this design phase are represented in Figure 1. This comprehensive structural blueprint illustrates that a singular primary actor, designated as the User, serves as the main operator interacting directly with the system's core capabilities. The behavioral specifications mapped within the diagram encapsulate critical workflows required for holistic diabetes management. Following the functional modeling, the system's structural data architecture was mapped to support high-performance data operations. The logical data layout was designed as a collection of hierarchical documents optimized for a NoSQL document-store model, ensuring seamless synchronization and fast query execution times for historical health data. The specific schematic configuration of the database collections, fields, and relational attributes is structured in Figure 2. This schema centers around a primary User node mapped directly to multiple sub-collections, including ProfileInfo, DiabetesData, and Medication. It also anchors independent data nodes for automated health Recommendations, Articles, and Shares, thereby establishing a lightweight yet cohesive relational tree that minimizes write latency during real-time client synchronization. Next Database Structure on Figure 2.

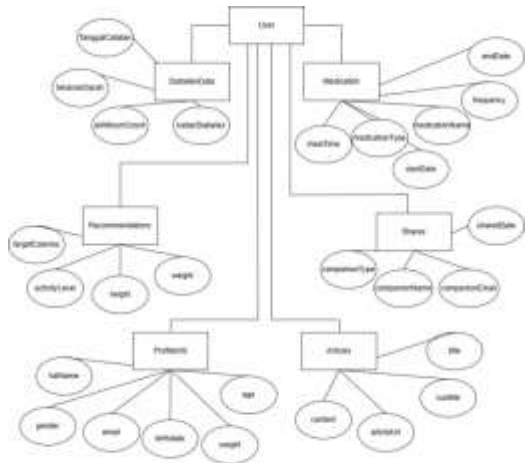

Figure 2. Database Structure

The subsequent implementation phase translated these structural and functional designs into a production-ready application using Android Studio as the primary Integrated Development Environment (IDE) with Kotlin as the native programming language. The system architecture enforces the Model-View-ViewModel (MVVM) design pattern to strictly decouple business logic from user interface components, which heavily enhances code modularity and eases automated testing procedures. For the backend infrastructure, the application fully integrates the Firebase cloud ecosystem. Firebase Authentication is utilized to handle secure user onboarding via robust credential encryption, while the Firebase Realtime Database serves as the persistent storage layer that synchronizes user health logs across the client app instantaneously. Additionally, Firebase Cloud

Messaging (FCM) and Firebase Storage are incorporated to handle background execution for medication notification triggers and the delivery of multimedia educational assets, respectively.

The final phase of the research methodology involved a rigorous three-tiered evaluation framework to validate the system's viability. First, code quality testing was performed using the built-in Android Studio Inspect Code tool to systematically identify correctness issues, potential memory leaks, or syntax non-conformities across the entire codebase. Second, automated functional testing was executed via the Espresso testing framework using Black Box testing methodologies to verify that crucial workflows—such as authentication tokens, database write-and-read cycles, and notification alerts—operate exactly as specified without runtime crashes. Third, a usability evaluation was conducted directly with ten diagnosed diabetes patients who completed a Likert-scale questionnaire based on standardized metrics, assessing the application's effectiveness in accurate data recording, its perceived usefulness in daily diabetes care, and overall interface satisfaction.

3. Result and Discussion

The DiabetesKu application has been successfully implemented and deployed in accordance with the proposed architectural and functional design models. The application code is managed via a Git version control system hosted on GitHub, ensuring clean package organization enforced by the MVVM pattern. The core user interface of the mobile application is rendered on the main dashboard screen, which serves as the central hub for independent patient management [14]. As illustrated in Figure 3, the dashboard utilizes a clean, high-contrast, user-friendly layout specifically optimized for diabetic patients who may suffer from mild visual impairments like retinopathy. The top header provides a personalized greeting ("Halo, Akmal") alongside an intuitive floating action message icon for quick communications.

Figure 3. DiabetesKu Main Dashboard Interface

The core functionalities are accessible via a simplified grid system consisting of six primary interactive modules Catatan Kesehatan (Health Record): Provides manual logging for blood glucose levels. During final deployment, this feature was optimized to include dynamic colored rings and visual status categories (e.g., an "Excellent" status in green for 120 mg/dL) to help elderly users instantly comprehend their metabolic condition without memorizing raw clinical ranges [15]. Tentang Diabetes (About Diabetes): Delivers structured, localized educational content regarding diabetes mellitus self-management. Pengingat Obat (Medication Reminder): Triggers automated push notifications backed by Firebase Cloud Messaging to ensure strict adherence to prescribed medication schedules. Berbagi Data (Data Sharing): Allows patients to safely export and share their visualized health graphs and reports with family members or medical staff.

Diet dan Nutrisi (Diet and Nutrition): Features a robust tracking database that visualizes nutrient breakdowns. For instance, selecting a standard local dish like "Nasi Teri" yields a precise energetic reading of 220.8 kcal along with its structural breakdown: 41.4 g of Carbohydrates, 4.42 g of Fats, and 4.42 g of Proteins, fully adjustable by mealtime and portion sizes [16]. Tanya Dokter (Ask Doctor): Integrates an external gateway facilitating instant medical consultation via pre-configured WhatsApp endpoints. Prior to user deployment, the application underwent rigorous code optimization using the Android Studio Inspect Code suite, correcting 2 critical errors within the codebase. Subsequently, functional automated testing was carried out using the Espresso framework. Ten distinctive testing scenarios were established to validate the critical logic pathways of the system. The exact specifications, test inputs, and behavioral results of these 10 scenarios are compiled in Table 1 below [17]. Next Black Box Testing Scenarios and Functional Verification on Table 1.

Table 1. Black Box Testing Scenarios and Functional Verification

No	Module	Test Scenario	Expected Behavior & Output Verification
1	User Authentication	Registration & secure login process	Successful token creation and redirect to dashboard
2	Blood Glucose Log	Manual input of mg/dL values	Dynamic color indicator and category tag display
3	Alarm Trigger	Scheduled medication timestamp	Local notification alert pops up on the system tray
4	Nutritional Query	Search menu keyword (e.g., "Nasi Teri")	Instant rendering of exact kcal and macronutrient values
5	History Reporting	Graph rendering of past logs	Real-time plot updates from Firebase Database
6	WhatsApp Gateway	Clicking "Tanya Dokter" module	Seamless application intent switch to external API
7	Data Export	Triggering "Berbagi Data" share	Successful generation and sharing of the report image
8	Firebase Sync	Data insertion offline to online	Local data synchronization with NoSQL storage
9	Profile Management	Editing user medical baseline info	Database update and immediate update on the UI profile
10	Educational Carousel	Swiping through diabetes articles	Correct retrieval of storage media assets without lag

All 10 scenarios achieved a 100% success rate, confirming that the decoupling of logic enforced by the

MVVM architecture prevented runtime exceptions and functional bottlenecks. To provide a granular understanding of the user evaluation metrics, the post-test questionnaire was structured into 15 specific assessment items, compiled in Table 2. These items were systematically classified into three core usability dimensions derived from standard software quality models: effectiveness, which measures the user's ability to complete tasks accurately; usefulness, which assesses the perceived clinical and practical value of the features; and satisfaction, which quantifies the visual appeal, navigational ease, and cognitive comfort of the interface [18] [19]. Next Usability Evaluation Questionnaire on Table 2.

Table 2. Usability Evaluation Questionnaire

No	Usability Parameter	Questionnaire Assessment Item
1	Effectiveness	Q1: Do you feel this application is effective enough in monitoring your blood glucose levels? Q2: Does this application help you remember your medication schedules well? Q3: Is this application easy to understand and use without requiring significant external assistance? Q4: Does the medication reminder feature in the application make it easier for you to follow your treatment schedule on time? Q5: Can this application assist you in controlling and monitoring your diabetes condition independently?
2	Usefulness	Q6: Does this application provide sufficient information regarding diabetes management, including diet and physical activity? Q7: Do you feel this application can help you prevent diabetes complications in a more structured manner? Q8: Does the diet and nutrition feature in the application provide helpful information for choosing diabetes-friendly healthy foods? Q9: Do you feel this application provides adequate guidance regarding exercise or physical activities suitable for diabetes patients? Q10: Do you frequently use the application to record your blood glucose levels?
3	Satisfaction	Q11: Are you satisfied with the user interface design of this application? Q12: Do you feel this application is easy to navigate and that its features can be accessed with ease? Q13: Do the color design and icons within the application help you better comprehend your health data? Q14: Do you feel the doctor consultation feature via the application provides significant benefits? Q15: Does this application provide a sense of security since you can share your health data with doctors or family members?

The usability field test involved 10 active diabetic patients who evaluated the application across 15 questions. Tabulated survey responses demonstrated an exceptionally positive perception of the system, with 65.3% of the responses marking "Strongly Agree" (Score 5), 31.3% marking "Agree" (Score 4), and a minor 3.3% selecting "Neutral" (Score 3). Crucially, no respondents registered a negative score of "Disagree" or "Strongly Disagree". Cumulatively, 91.7% of the target users reported being satisfied to highly satisfied with the operation of DiabetesKu. The analytical breakdown of the usability metrics divided into standard categories is presented in Table 3.

Table 3. Usability Parameter Performance Breakdown

No	Usability Parameter	Average Score	Empirical Interpretation
1	Effectiveness	90.4%	Highly effective in facilitating accurate independent health records
2	Usefulness	92.4%	High clinical value in everyday diabetes lifestyle control
3	Satisfaction	92.4%	High aesthetic appeal, clear text readability, and smooth navigation
	Usability Average	91.7%	Excellent Operational Viability / High Readiness

The attributes that received the highest individual appreciation from the patients were interface navigation ease (mean score of 4.9 out of 5.0), the perceived security of the health report distribution mechanism (mean score of 4.9 out of 5.0), and the cognitive simplicity of the workflow (mean score of 4.8 out of 5.0). These insights conclusively show that pairing a modular codebase (MVVM) with reactive cloud synchronization (Firebase) yields an highly reliable, adaptive, and patient-focused mobile health environment capable of boosting chronic illness self-care compliance.

The remarkably high score achieved in the effectiveness and usefulness dimensions (averaging over 90%) is technically attributed to the reactive data programming model enforced by the MVVM architecture. By leveraging Kotlin’s state management properties, any localized database operation executed by the user such as updating blood glucose levels or logging macronutrient counts triggers an immediate, non-blocking UI state refresh [20]. This structural behavior eliminates typical mobile application latencies and prevents interface freezing, which provides an exceptionally smooth operational workflow for patients with minimal digital literacy. Furthermore, the real-time background synchronization managed by the Firebase Realtime Database guarantees that user inputs are safely persisted and cached locally if the network drops, ensuring data integrity during spontaneous clinical monitoring routines.

In terms of user satisfaction, the positive feedback regarding visual readability and navigational simplicity validates the implementation of high-contrast design principles tailored for diabetic patients. Given that chronic hyperglycemia frequently correlates with mild retinopathy and diminished visual acuity, the interface was purposefully stylized using a spacious grid system, clear typography, and color-coded status rings to convey complex metabolic metrics without cognitive strain. The direct intent-switch gateway linking the application to a pre-configured WhatsApp endpoint (Tanya Dokter) also emerged as a highly appreciated feature, as it successfully bridges the gap between independent home care and professional medical validation. Ultimately, these usability outcomes indicate that combining a decoupled, modular frontend with an automated cloud backend yields a resilient digital health solution that effectively drives self-management compliance among diabetes patients.

4. Conclusion

This research successfully developed and evaluated "DiabetesKu", a mobile-based health monitoring application tailored specifically to enhance self-management compliance among diabetes mellitus patients in Indonesia. By implementing Modern Android Development (MAD) tech stacks including the native Kotlin programming language and a decoupled Model-View-ViewModel (MVVM) architecture the application achieves high code modularity and structural stability. The seamless integration with the Firebase cloud ecosystem ensures secure user authentication, instant cross-device data synchronization through the Firebase Realtime Database, and automated medication reminders via Firebase Cloud Messaging. Empirical evaluations demonstrate that the application is highly reliable and viable for daily clinical support. Automated functional testing across ten critical system scenarios yielded a 100% success rate, confirming the robust operational logic of the MVVM framework. Furthermore, the usability evaluation involving active diabetes patients resulted in a remarkable cumulative satisfaction rate of 91.7%, with users highly praising the system's effectiveness, usefulness, and intuitive interface layout. Ultimately, "DiabetesKu" addresses the critical gaps in independent chronic illness care by providing a practical, high-performance digital intervention that can successfully mitigate the risks of severe long-term diabetic complications. For future research and development, several advancements are recommended to expand the application's capabilities. First, integrating wearable IoT devices (such as continuous glucose monitors or smartwatches) would allow automated and seamless health data collection, reducing manual input errors. Second, incorporating Machine Learning algorithms could enable predictive health analytics, giving patients personalized risk assessments and proactive warning systems based on their historical glucose trends. Lastly, expanding the platform into a multi-platform application using Kotlin Multiplatform (KMP) would widen user accessibility, allowing seamless deployment for iOS users while maintaining shared business logic with the current Android system.

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