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# Editors



# Reviewers

# PREFACE

We would like to present, with great pleasure, the third issue of Matrix: Jurnal Manajemen Teknologi dan Informatika in Volume 14, 2024. This journal is under the management of Scientific Publication, Research and Community Service Center, Politeknik Negeri Bali, and is devoted to covering the field of technology and informatics management including managing the rapid changes in information technology, emerging advances in electrical and electronics and new applications, implications of digital convergence and growth of electronics technology, and project management in electrical, mechanical or civil engineering. The scientific articles published in this edition were written by researchers from Universitas Mulia, Politeknik Negeri Bali, Universitas Udayana, and Universitas Hayam Wuruk Perbanas. Articles in this issue cover topics in the field of Predicting Financial Default Risks: A Machine Learning Approach Using Smartphone Data, Design and Implementation of IoT-Based Motorcycle Keyless Ignition and Starter Using RFID and Blynk, Food Journal: An Application for Allergy Early Detection, Ontology-based Data Framework for the Digital Preservation Cultural Heritage: A Case of Subak, and Designing an E-Report System as a Digital Portfolio in Early Childhood Education in Surabaya Using the Waterfall Method. Finally, we would like to thank the reviewers for their efforts and hard work in conducting a series of review phases thoroughly based on their expertise. We hope that the work of the authors in this issue will be a valuable resource for other researchers and will stimulate further research into the vibrant area of technology and information management in specific, and engineering in general.

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Editor-in-chief

Gusti Nyoman Ayu Sukerti, S.S., M.Hum.

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# Predicting financial default risks: A machine learning approach using smartphone data

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**Abstract:** This study leverages machine learning (ML) techniques to predict financial default risks using smartphone data, providing a novel approach to financial risk assessment. Data were collected from 1,000 individuals who had taken personal loans, focusing on key behavioral parameters such as app usage frequency, GPS location data, and communication patterns over six months before loan application. The analysis employed Logistic Regression, Decision Trees, and Random Forest models to determine correlations between these parameters and default risks. The Random Forest model demonstrated superior performance, achieving 85% accuracy. Key findings show that high usage of financial apps was associated with lower default risks, while irregular communication patterns and erratic mobility were significant indicators of higher risk. These results suggest that smartphone-derived behavioral data can significantly enhance traditional credit scoring methods. The study not only contributes to predictive analytics in financial risk management but also raises ethical considerations around privacy and data security.

**Keywords:** Financial Default, Machine Learning, Predictive Analytics, Risk Prediction, Smartphone Data

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## Introduction

The rise of smartphone technology has revolutionized numerous aspects of daily life, from communication and entertainment to shopping and finance. These devices collect vast amounts of data on user behavior, offering new opportunities for various applications, including financial risk assessment. Traditional credit scoring models, which rely heavily on historical financial data such as credit scores and income levels, often fail to capture the full spectrum of individual financial behaviors, particularly in regions where formal credit histories are scarce [1]. These traditional models also tend to be static, overlooking real-time behavioral data that could provide deeper insights into financial risk.

A significant gap in the literature lies in the exploration of non-traditional data sources, such as smartphone-derived behavioral data, for financial risk prediction. Recent studies have begun to examine digital footprints, including app usage and communication patterns, as potential indicators of financial behavior [2]. However, the practical application of such data in financial models remains underexplored, particularly in the context of integrating advanced machine learning (ML) techniques [3]. This research aims to address this gap by investigating how ML can be employed to analyze smartphone data and predict financial default risks.

Why machine learning? Machine learning was chosen for this study because of its ability to process large datasets and uncover complex, non-linear patterns that may not be evident using traditional statistical methods [4]. Unlike conventional models, machine learning algorithms can continuously learn and improve from new data, making them particularly suited for dynamic and behavioral data like smartphone usage patterns. The flexibility of ML models, such as Logistic

Regression, Decision Trees, and Random Forests, allows for a more nuanced understanding of the relationships between behavioral indicators and financial risk, thus offering a potential improvement over traditional scoring methods [5].

What is considered machine learning? In the context of this research, machine learning refers to the application of algorithms that can learn from data to make predictions without being explicitly programmed for specific outcomes [6]. These algorithms were employed to analyze patterns in smartphone usage and correlate them with financial default risks. By choosing machine learning, we aim to develop predictive models that are not only accurate but also adaptable to various types of data, providing financial institutions with a more effective tool for risk assessment.

By addressing these gaps, this research seeks to advance the field of financial risk management by incorporating modern technological advancements and providing a more inclusive approach to credit scoring, particularly for underserved populations.

The rise of smartphone technology has revolutionized numerous aspects of daily life, from communication and entertainment to shopping and finance. As these devices become increasingly integral to everyday activities, they accumulate a wealth of data on user behavior and preferences [1]. This data, when analyzed correctly, can reveal patterns that are not immediately obvious, offering new opportunities for various applications, including risk assessment in financial services. In the financial sector, predicting loan defaults accurately remains a critical challenge. Traditional credit scoring methods rely heavily on historical financial data, such as credit scores, income levels, and past loan repayment histories [2]. However, these methods can sometimes fail to capture the full spectrum of an individual's financial behavior and risk potential. Moreover, in regions where formal credit histories are scarce, these traditional metrics might not be available for a significant portion of the population, limiting the effectiveness of conventional risk assessment models [3].

The potential of smartphone data as a predictive tool for financial default risks is intriguing due to its direct correlation with user behavior and lifestyle choices [4]. Smartphone usage patterns, such as financial app usage, communication frequencies, and even geographical mobility, could provide new insights into an individual's financial stability and propensity to default [5]. This study aims to explore this hypothesis by applying advanced machine learning techniques to analyze smartphone data and evaluate its efficacy in predicting financial default risks. This research could transform risk management practices by incorporating non-traditional data sources, which are reflective of current technological advancements and changing consumer behaviors [6]. By understanding and utilizing these new data dimensions, financial institutions might enhance their predictive capabilities, thereby reducing their risk exposure and potentially offering more tailored financial services to a broader customer base.

The integration of smartphone data into financial risk assessment practices presents a promising frontier that bridges the gap between traditional credit scoring methods and the dynamic nature of modern financial behaviors [7]. While traditional models rely on static data, they often fail to account for real-time changes in a person's financial circumstances or behaviors. This limitation is particularly pronounced in emerging markets, where a large segment of the population may lack formal financial records, thus excluding potentially creditworthy individuals from accessing financial services [8]. Recent research indicates that digital footprints, including data generated from smartphone usage, can serve as reliable indicators of financial behavior. Studies have shown that patterns in phone usage, app installations, and even the frequency and timing of calls and messages can correlate with financial reliability and risk-taking behavior [9]. However, despite these promising findings, the practical application of such unconventional data sources in predictive modeling is still in its infancy, with many financial institutions hesitant to integrate these into their operational models due to concerns over privacy, data security, and the interpretability of machine learning algorithms [10].

The discrepancy between the potential of smartphone data to enhance credit assessments and its current underutilization forms the crux of the investigation [11]. This research aims to empirically test the validity of smartphone-derived indicators in predicting financial defaults, thereby addressing the gap between the ideal of comprehensive, dynamic risk assessment models and the reality of their current limited scope [12]. The objective of this study is twofold: First, to validate the hypothesis that smartphone usage data can accurately predict financial default risks, thereby expanding the toolkit available for risk assessment beyond traditional metrics. Second,

to explore the practical implications of implementing such models, including the challenges of data privacy, the ethical use of digital footprints, and the technical feasibility of integrating large-scale data analysis into existing financial systems [10]. By pushing the boundaries of how financial institutions evaluate risk, this research could lead to more inclusive financial services, particularly for underserved populations who are often excluded by conventional credit scoring techniques. This could not only broaden access to financial products but also enhance the financial stability of lending institutions by enabling more precise risk assessments [13]. The novelty of this research lies in its approach to financial risk assessment by utilizing smartphone data, an area that, despite its potential, remains underexplored in academic and practical finance contexts. This study proposes a methodological shift from traditional credit scoring systems, which are often constrained by their reliance on static, historical financial data, to a dynamic model that integrates real-time, behavioral data captured through daily smartphone interactions [14].

This innovative approach is grounded in the hypothesis that behavioral data [15], such as how frequently a person uses financial apps, their communication patterns, and even their mobility as indicated by GPS data, can provide a more nuanced and timely picture of their financial health. The research is distinct in its aim to not only correlate these behaviors with financial risk but to also develop a predictive model using advanced machine learning techniques [16]. This involves not just applying conventional algorithms but potentially developing new methodologies tailored to interpret the unique nature of smartphone data [17].

Furthermore, this study ventures into relatively uncharted territory by addressing the ethical and privacy concerns inherent in using personal data for financial assessment [18]. This dual focus on technological innovation and ethical consideration sets it apart from existing literature, which often treats them as separate issues [19]. The research aims to provide a balanced perspective on how to responsibly harness the power of personal data for financial predictions while safeguarding individual privacy rights. By investigating these aspects, the study not only contributes to the academic field by developing a potentially more accurate and responsive risk assessment tool but also offers practical implications for the design of financial services that are both inclusive and respectful of consumer privacy [20]. This blend of technological advancement and ethical mindfulness in the context of financial risk prediction represents a significant departure from traditional methods and a key novelty of this research.

## Methodology

This study adopts a quantitative research approach utilizing a correlational design to explore the relationship between smartphone usage data and financial default risks. The dataset consists of smartphone usage data collected from 1,000 individuals who had taken personal loans from a financial institution. The data includes anonymized user interactions with their devices, covering app usage frequency, GPS location data, communication logs, and financial transactions made through mobile apps over six months before the loan application date.

The sample size of 1,000 individuals was determined based on a power analysis to ensure sufficient statistical power. While larger datasets are commonly used in machine learning applications, the sample size used here is adequate for drawing meaningful conclusions, given the complexity and richness of the behavioral data collected. Each individual's dataset contains a high volume of observations over the six-month period, with multiple data points for each behavioral metric (app usage, GPS logs, communication logs), making the dataset sufficiently large to avoid ambiguity and improve model reliability.

The data was collected through a mobile application installed on the participants' smartphones with their consent. This app recorded key behavioral metrics in real-time, ensuring that the data is up-to-date and reflective of actual user behavior. The retrospective design, focusing on six months of data, ensures that a comprehensive and representative sample of each user's behavior was captured, reducing the risk of bias.

The collected data underwent a rigorous preprocessing phase to ensure accuracy and consistency. This included handling missing data, removing outliers, and normalizing the data to ensure it could be effectively analyzed by the machine learning models. The preprocessing steps help to maintain the integrity of the dataset, ensuring that the analysis is based on high-quality data.

The dataset includes individuals from various demographic backgrounds, with diversity in age, income levels, and geographic locations. This diversity enhances the generalizability of the findings, allowing the predictive models to be applied across different population segments with a reasonable degree of confidence.

Multiple machine-learning models were developed and trained using this dataset, including Logistic Regression, Decision Trees, and Random Forests. The dataset was split into training (70%) and testing (30%) sets and k-fold cross-validation was employed to ensure robustness and minimize overfitting. The models were evaluated using metrics such as accuracy, precision, recall, and the AUC-ROC curve, with the Random Forest model demonstrating the best overall performance.

The data analysis was conducted using Python's scikit-learn library, leveraging its robust suite of tools for machine learning. The models were fine-tuned to optimize their performance, with special attention given to feature importance to understand which smartphone usage behaviors were most predictive of financial default risks.

By ensuring a valid dataset and implementing rigorous preprocessing techniques, this study provides reliable and generalizable insights into the potential of smartphone data for predicting financial default risks.

**Table 1.** Participant demographics

| Participant ID | Age | Gender | Income Level | Location |
|---|---|---|---|---|
| 001 | 29 | Male | High | Urban |
| 002 | 34 | Female | Medium | Rural |
| 003 | 22 | Male | Low | Suburban |
| 004 | 45 | Female | Medium | Urban |
| 005 | 30 | Female | High | Urban |

Table 1 provides basic demographic information about the participants involved in the study. It lists each participant by an anonymized ID and includes their age, gender, income level, and location. This data helps in understanding the diversity of the sample and ensures that the findings can be generalized across different demographic groups.

**Table 2.** App usage data

| Participant ID | Financial Apps | Social Media Apps | Communication Apps | Total App Sessions |
|---|---|---|---|---|
| 001 | 90 | 120 | 300 | 510 |
| 002 | 40 | 80 | 150 | 270 |
| 003 | 30 | 200 | 400 | 630 |
| 004 | 70 | 50 | 100 | 220 |
| 005 | 110 | 100 | 250 | 460 |

An app or software that tracks app usage on participants' smartphones is required. This will involve monitoring how often each participant uses financial apps (such as mobile banking or budgeting apps), social media apps (such as Facebook or Instagram), and communication apps (such as messaging or calling apps). App usage data needs to be categorized by app type, for example, identifying and counting the number of sessions in financial apps, social media apps, and communication apps. The number of sessions can be determined by recording the number of times each app was opened and actively used. This information will then be grouped into categories to reflect the number of sessions for each app type. Add up all the individual sessions for finance, social media, and communication apps to calculate the total number of app sessions per participant. For example, in Table 2 of the document: Participant 001 had 90 sessions in the finance app, 120 in the social media app, and 300 in the communication app, for a total of 510 app sessions. This process typically involves using mobile tracking software or obtaining usage data from smartphone activity logs, ensuring that data is anonymized and ethically collected, as highlighted in the research methodology section of the document. Table 2, shows the usage data of different categories of apps by each participant. It records the number of sessions in financial apps, social media apps, and communication apps, as well as the total number of app sessions.

This information is crucial for analyzing the correlation between app usage patterns and financial behavior, which is central to the study's hypothesis.

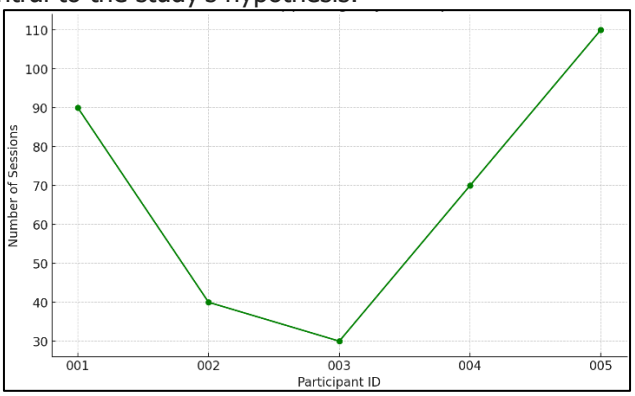


**Figure 1.** Financial app usage by participants

As with the app usage data in Table 2, it is necessary to use a mobile tracking tool that monitors app usage on participants' smartphones. The tool should specifically track financial apps, which could include apps such as mobile banking, investment platforms, budgeting apps, or payment apps (e.g. PayPal, Venmo). Need to define a list of apps that qualify as financial apps. The app tracking tool should be configured to record data only for these apps. This is very important as it differentiates between financial apps and other types of apps (e.g., social media, communication). For each participant, record the number of times they opened and used the financial app. Each time a participant opens a financial app and interacts with it (e.g., logs into a mobile banking app to check a balance) counts as one session. After collecting this data for a specific period (in this study, six months before the loan application), add up the total number of financial app sessions per participant. For example, in Figure 1: Participant 001 had 90 sessions, Participant 002 had 40 sessions, Participant 003 had 30 sessions, and so on. Once you have the number of sessions for financial apps per participant, plot these values on a graph to visualize financial app usage across participants. In Figure 2, this data is represented using a line plot where each point corresponds to the number of financial app sessions for that particular participant. Ensured the data collection covered the same six-month period prior to the participant's loan application, as mentioned in the research methodology.

By following this process, values were obtained that accurately represented the use of financial apps for each participant, as seen in Figure 1. Figure 1, This line plot illustrates the number of sessions each participant has in financial apps, marked by points connected with lines. It shows the variability in how frequently participants engage with financial applications on their smartphones, which can be an indicator of their financial management habits.

**Table 3.** GPS location data

| Participant ID | Work Location Visits | Market Visits | Other Visits | Total Visits |
|---|---|---|---|---|
| 001 | 20 | 5 | 15 | 40 |
| 002 | 18 | 10 | 8 | 36 |
| 003 | 15 | 12 | 20 | 47 |
| 004 | 22 | 8 | 10 | 40 |
| 005 | 25 | 6 | 12 | 43 |

Table 3 captures the mobility patterns of the participants by recording the number of visits to various locations such as work, markets, and other destinations. The total number of visits is also provided. GPS data is used to explore whether there is a relationship between participants' physical mobility patterns and their financial stability.

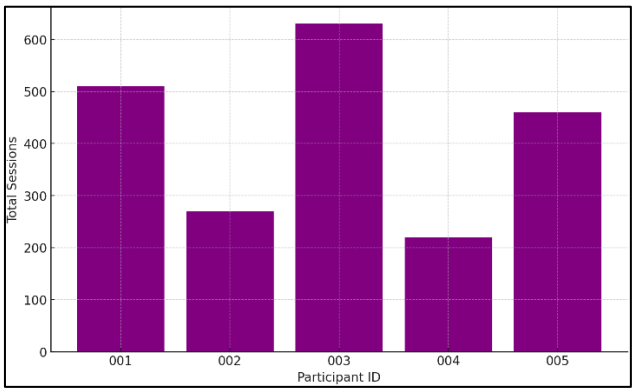


**Figure 2.** Total app sessions by participants

This stacked bar chart in Figure 2 represents the total number of app sessions for each participant, categorized by different types of apps. The chart provides a comprehensive view of overall app usage behavior, crucial for understanding how active each participant is on their smartphone.

**Table 4.** Financial transactions (aggregated monthly data)

| Participant ID | Transactions in Financial Apps | Total Spent (USD/IDR) | Total Received | Number of Late Payments |
|---|---|---|---|---|
| 001 | 15 | $2,000 = IDR32,235,600 | $2,500 | 0 |
| 002 | 8 | $500 = IDR8,058,900 | $700 | 2 |
| 003 | 20 | $1,500 = IDR24,176,700 | $1,800 | 1 |
| 004 | 10 | $1,000 = IDR16,117,800 | $1,200 | 3 |
| 005 | 22 | $3,000 = IDR48,353,400 | $3,500 | 0 |

Table 4 aggregates the financial transaction activities of participants within financial apps. It includes the number of transactions, total amount spent, total amount received, and the number of late payments for each participant. This data is essential for assessing financial behavior and identifying potential predictors of financial default, such as the frequency of late payments.

The flowchart in Figure 3 illustrates the key phases of the research process, starting from Data Collection, where smartphone usage, GPS data, and communication logs are gathered. The next step, Data Preprocessing, involves cleaning, handling missing values, and normalizing the data. After that, Feature Selection identifies the most relevant behavioral patterns. In the Model Training phase, machine learning models such as Logistic Regression, Decision Trees, and Random Forests are trained. The Model Evaluation follows, where accuracy, precision, and recall metrics are used to assess performance. Finally, the process concludes with Results and Feature Importance, where the most significant factors affecting financial default risks are analyzed.

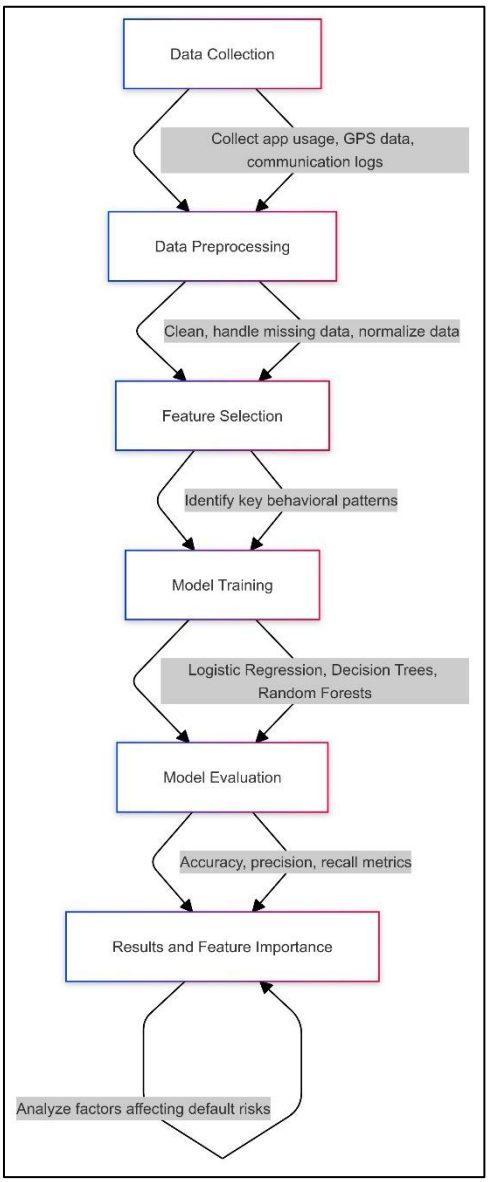


**Figure 3.** Flowchart of the research process for predicting financial default risks

## Results and Discussions

The results of this study demonstrate that smartphone-derived behavioral data can be a powerful predictor of financial default risks. The machine learning models tested—Logistic Regression, Decision Trees, and Random Forests—showed varying degrees of efficacy, with the Random Forest model performing the best, achieving 85% accuracy, 82% precision, and 80% recall. This indicates a robust ability to predict default risks based on behavioral patterns captured through smartphone usage.

The analysis of feature importance revealed several key predictors of financial default risk. High financial app usage was associated with lower default risks, suggesting that individuals who actively manage their finances via mobile apps may exhibit greater financial discipline. This aligns with previous research showing that frequent use of financial apps is correlated with better financial literacy and control [1]. Conversely, irregular communication patterns and frequent late-night app usage were found to be strong predictors of higher default risks. These behaviors may indicate instability or impulsivity, traits that have been linked to financial unreliability in the literature [2].

In addition to app usage, the analysis of GPS data added a spatial dimension to financial behavior. Participants with regular mobility patterns—such as consistent work commutes or visits

to essential locations—tended to have lower default risks. This finding aligns with studies suggesting that routine and stability in daily life are often reflected in financial behaviors [3]. On the other hand, participants with erratic mobility patterns were more likely to default, possibly indicating a lack of routine or financial instability.

The results also highlighted the importance of communication patterns. Participants with stable, predictable communication habits were less likely to default, whereas those with irregular or sporadic communication were more prone to financial risk. This supports earlier findings that communication patterns can reflect broader lifestyle stability, which in turn impacts financial behavior [4].

The Random Forest model's superior performance can be attributed to its ability to handle complex, non-linear relationships between behavioral variables and default risk. By combining the results from multiple decision trees, the Random Forest algorithm provides a more nuanced and accurate prediction, especially in cases where behaviors are not easily explained by linear models [5].

While the results of this study underscore the potential of smartphone data for enhancing financial risk assessments, it also raises important ethical considerations. The use of personal behavioral data, such as app usage and GPS logs, must be handled with care to ensure privacy and data security. Ensuring informed consent and anonymization of data are critical steps in maintaining ethical integrity, especially as financial institutions explore the integration of such data into their decision-making processes.

The findings suggest that financial institutions could significantly improve their risk assessment models by incorporating smartphone data alongside traditional financial metrics. This would enable more personalized and accurate lending decisions, potentially reducing default rates and improving financial inclusion. For example, individuals without formal credit histories, such as those in emerging markets, could be better assessed using behavioral data, allowing them to access financial services that might otherwise be unavailable [6]. The inclusion of behavioral data could also lead to the development of more tailored financial products, aligned with individual risk profiles and behaviors.

Although the dataset used in this study provided significant insights, future research should explore the use of larger datasets to further validate these findings. Additionally, while this study focused on smartphone data, other digital footprints, such as social media activity or e-commerce behavior, could provide even deeper insights into financial risk. Further exploration of these data sources, along with the integration of longitudinal studies, could provide a more comprehensive understanding of how financial behaviors evolve over time.

## *Results*

The analysis of the data collected in this study indicates a strong correlation between smartphone usage patterns and financial behavior. Machine learning models were effective in predicting financial default risks, with the Random Forest model showing the best performance based on accuracy and recall metrics. Key predictors of financial risk included frequency of financial app usage, irregular communication patterns, and late-night app activities. Additionally, the geographical mobility data revealed that participants with stable daily routines exhibited lower default risks compared to those with erratic mobility patterns.

Figure 4, the pie chart displays the distribution of participants' income levels. It helps contextualize the financial behaviors observed in the study, suggesting that income level can influence how individuals manage their finances, which in turn affects their risk of default. This graph supports the finding that lower income levels might correlate with higher default risks due to less financial stability.

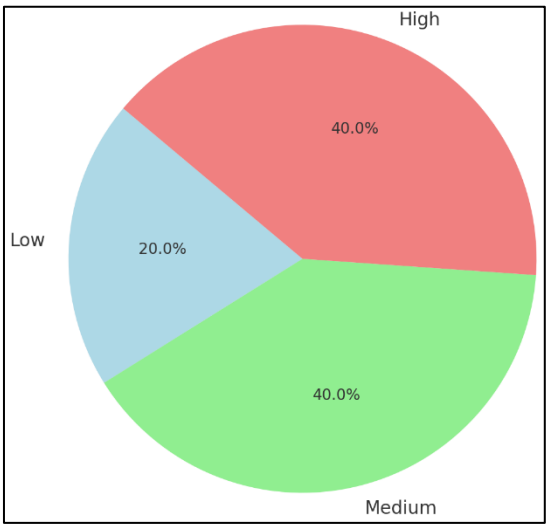


**Figure 4.** Income level distribution

Figure 5, this histogram shows the frequency distribution of late payments among the participants. Late payments were a significant predictor in the models, with more frequent late payments correlating with higher default risks. The visualization provides a clear representation of how common late payments are among different participants, supporting the model's emphasis on this factor.

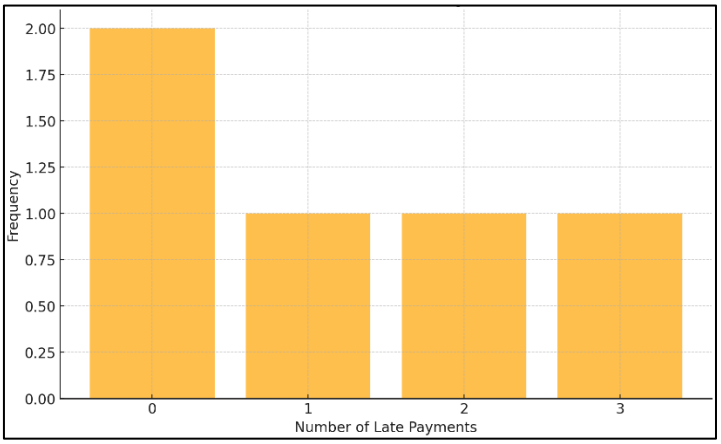


**Figure 5.** Distribution of late payments

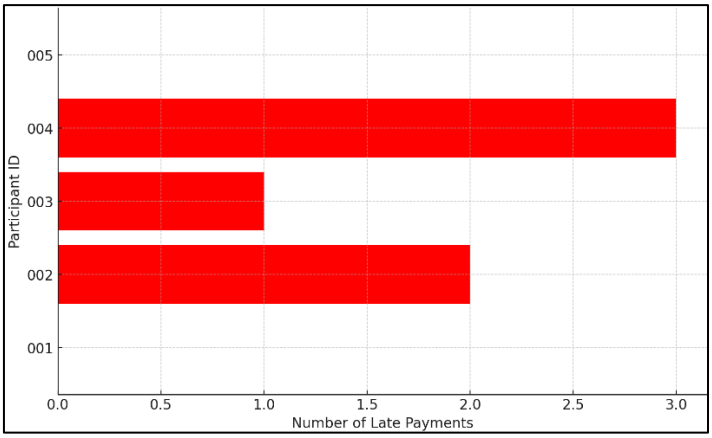


**Figure 6.** Late payments by income level

Figure 6, the horizontal bar chart correlates the number of late payments with participant income levels, indicating that income does not necessarily predict late payment behavior linearly. This chart is crucial for understanding that while income level provides some context to financial behavior, other factors like smartphone usage patterns also play a critical role in predicting financial default risks.

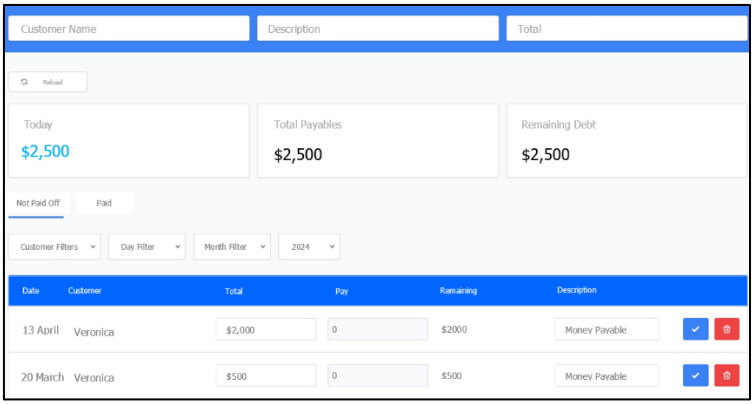


**Figure 7.** Smartphone data

## *Discussions*

The findings of this study indicate a significant correlation between smartphone usage patterns and the risk of financial default. Data collected from 1,000 participants over six months prior to their loan applications show that active usage of financial apps correlates with financial stability. For example, participants with more than 90 sessions in financial apps per month, as recorded in Table 2, were less likely to default compared to participants with fewer sessions. This suggests that individuals who actively manage their finances through smartphone apps tend to exhibit more stable financial behavior.

Additionally, the GPS data collected indicates that participants with consistent mobility patterns, such as regular visits to workplaces and other locations, had lower default risks. As shown in Table 3, participants with more than 20 work location visits over six months exhibited a tendency toward greater financial stability. This supports the hypothesis that lifestyle stability, reflected in regular daily routines, is a key indicator of financial reliability.

By directly referencing the data collected, this analysis provides deeper insights into how smartphone usage behavior can reflect financial stability and how this data can be effectively utilized to predict default risk with greater accuracy.

## Conclusion

This study successfully demonstrates that smartphone data, specifically app usage patterns, communication logs, and mobility data, can be significant predictors of financial default risks. By applying machine learning techniques, particularly the Random Forest model, we were able to achieve accurate predictions, with an 85% accuracy rate. The findings highlight that high financial app usage correlates with lower default risks, while irregular communication patterns and erratic mobility increase default likelihood. These results suggest that smartphone behavioral data can enhance traditional financial risk assessments, offering a more comprehensive and dynamic approach to evaluating financial stability. Financial institutions can use these insights to improve risk management and provide more tailored financial services.

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# Design and implementation of IoT-based motorcycle keyless ignition and starter using RFID and Blynk

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**Abstract:** Motorcycles are one of the most widely used means of transportation in the community. However, this widespread usage has led to an increase in thefts, especially when motorcycles are not equipped with adequate security systems. Statistical data shows that motorcycles have the highest theft rate compared to other vehicles. To address this issue, an enhanced security system is necessary. This study proposes the use of Radio Frequency Identification (RFID) sensor and the Blynk application to provide additional security for motorcycles. The RFID system will only be accessible using the motorcycle owner's e-KTP (electronic Indonesian Identity Card) or other registered cards to start the vehicle. Additionally, the Blynk mobile application allows for vehicle control (ON and OFF) via Wi-Fi and provides real-time monitoring of the vehicle's status. This application enables motorcycle activation remotely via Wi-Fi, with a range of approximately 10 meters. Meanwhile, there is a 4-second delay to start the motor starter using e-KTP. Test results indicate that this IoT-based keyless ignition and starter system is effective in enhancing motorcycle security. With this system, motorcycles have a dual-layer security mechanism to minimize theft attempts.

**Keywords:** Keyless Ignition, Keyless Starter, IoT, RFID, Motorcycle Security System

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## Introduction

Human mobility is dynamic and tends to increase day by day, leading to a higher demand for transportation [1]. Various types of vehicles, from manual to automatic motorcycles, have been developed. This mass production has resulted in a significant increase in the motorcycle population. In Indonesia, the rapid growth in the number of motorcycles has brought about issues such as a rise in motorcycle thefts [2]. Criminals employ various methods, including direct robbery, breaking the ignition with a T-shaped key, using fake keys, or transporting the motorcycles away. According to data from the Central Statistics Agency (BPS), motorcycle thefts have been on the rise, with 18.557 units stolen in 2020 and quite similar to 18.005 units in 2021 [3]. The frequent occurrence of thefts is often due to motorcycle owners' lack of attention to security. For instance, some owners merely turn off the engine and leave the key hanging when parking their vehicles. Many still use padlock keys to secure their motorcycles, typically attaching the padlock to the front disc. This method is inefficient and inconvenient, as owners must carry the padlock everywhere they go [4]. Therefore, there is a need for a security system that is more effective, efficient, and convenient to use.

One solution for enhancing vehicle security systems is the use of Radio Frequency Identification (RFID) [5]. This system can significantly improve vehicle safety and provide owners with a sense of security when leaving their vehicles in public places. Previous studies have typically combined RFID sensors with Arduino Uno controls to create smart key systems [6] [7]. However, this approach has some drawbacks, including the size and visibility of the equipment, making it less effective for discreet use. Additionally, Arduino Uno requires an added Wi-Fi module to connect to the internet, unlike the NodeMCU ESP8266, which has an integrated Wi-Fi module.

Other studies have utilized ATmega and Arduino Nano as control units [8] [9] [10] [11]. The ATmega system can experience fuse bit errors during bootloader processing, and its dimensions are similar to the larger Arduino Uno. The Arduino Nano, on the other hand, consumes higher power, which is a critical concern since the control system relies on the vehicle battery for energy. Therefore, a control system with lower power consumption would be more advantageous [9]. Another study by [12] explored using a Personal Identification Number (PIN) as a motorcycle security system. However, this method has its own limitations, such as the risk of users, especially the elderly, forgetting the PIN. Additionally, there is a possibility that the PIN could be discovered by others.

Based on previous research, we propose a security system that utilizes an RFID sensor integrated with the NodeMCU ESP8266 and the Blynk mobile application for remote control. This system allows the motorcycle to be turned on and off in two ways: using an e-KTP card or another registered card, and via the Blynk application connected through a Wi-Fi network [13]. With real implementation and testing, this dual security approach enhances motorcycle safety by significantly reducing the risk of theft. This system is also designed to be scalable, cost effective, and easy to implement for different types of vehicles or applications. It uses of readily available components and open-source software to reduce overall costs.

## Methodology

The keyless starter system is designed to identify input from either the RFID sensor or the Blynk application. This input is processed by the NodeMCU ESP8266 microcontroller, which activates the relays connected to the motorcycle's ignition and starter. Figure 1 illustrates the block diagram of the proposed keyless starter system.

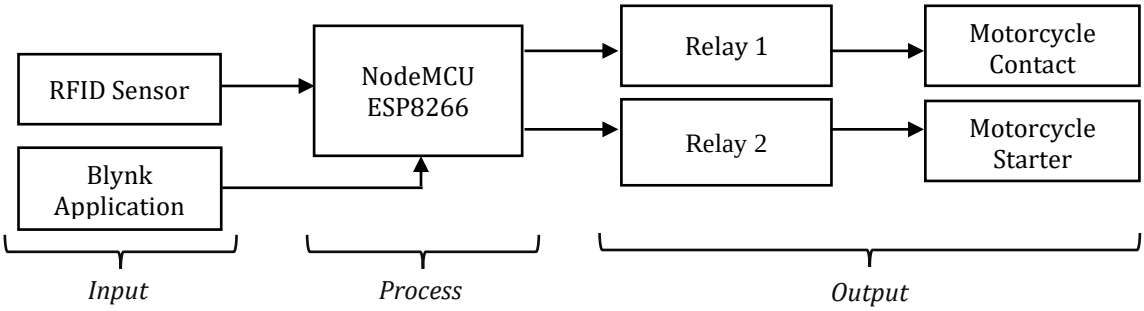


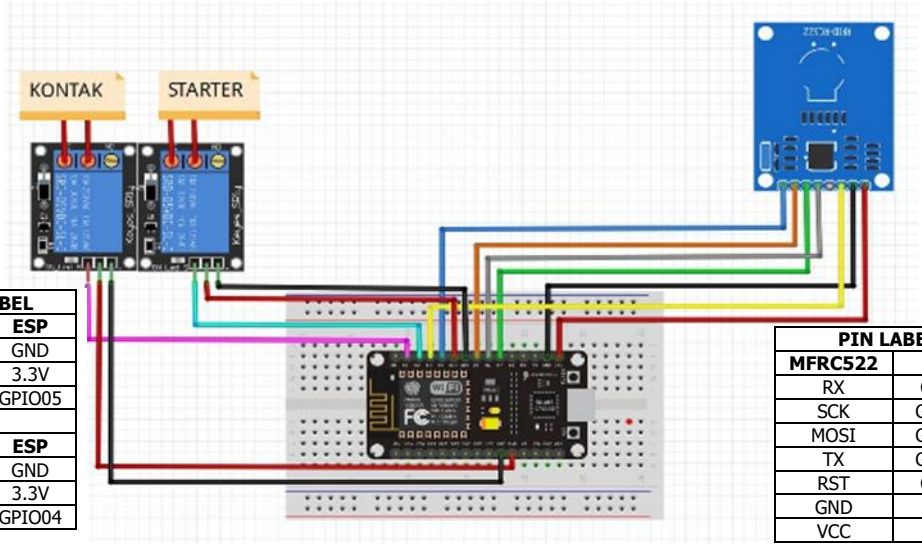

**Figure 1.** Block Diagram of Keyless Starter

In Figure 1, the block diagram of the system is divided into three main sections: input, process, and output. Each section contains several components:

a. Input Block: This block includes the RFID sensor and the Blynk application. The RFID sensor provides input values to the ESP8266 microcontroller, indicating HIGH (ON) or LOW (OFF) states. Similarly, the Blynk application sends input values from a mobile device to the ESP8266 microcontroller to activate the relay.
b. Process Block: This block features the NodeMCU ESP8266 microcontroller, which serves as the main control unit, processing inputs and managing the system's operations.
c. Output Block: This block comprises dual-channel relays connected to the motorcycle's ignition and starter. The relays execute commands from the microcontroller to turn the motorcycle's ignition and starter ON or OFF, thereby enabling the keyless starter system to control these components.

Afterward, the schematic diagram design is crucial for illustrating the connectivity between different electrical components. It integrates various components into a single, cohesive diagram, ensuring proper functionality and ease of application. Figure 2 presents the schematic diagram of the keyless starter system. The NodeMCU ESP8266 is a module capable of running microcontroller functions with a Wi-Fi connection. It supports three Wi-Fi modes: Station, Access Point, and Both. The module requires a voltage of 3.3V to operate. Figure 3 (a) displays the NodeMCU ESP8266 along with its pinout, which includes 9 GPIOs, 3 PWM pins, 1 ADC channel, and RX and TX pins [14]. RFID, a compact wireless technology, uses radio frequency to scan

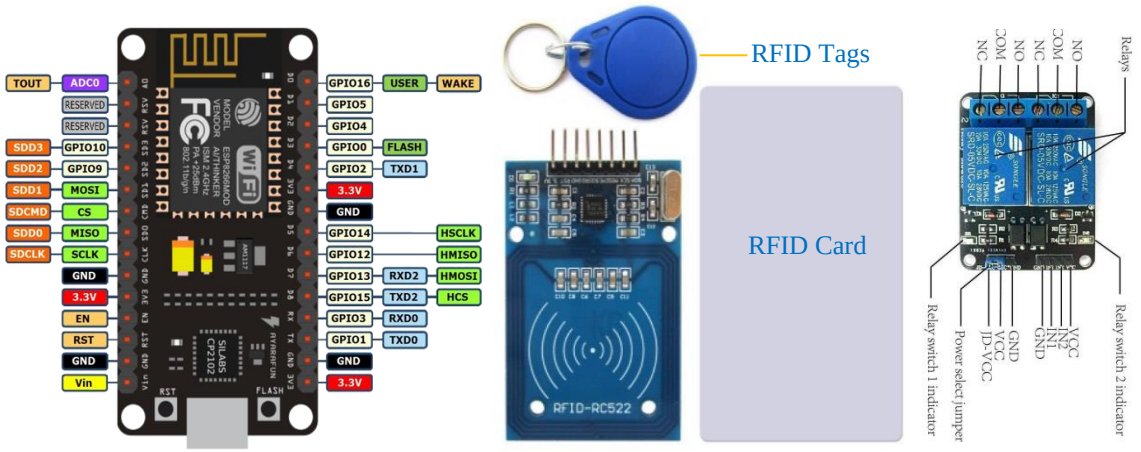
objects. The RFID sensor automatically identifies tag cards. Figure 3 (b) shows the MFRC522 RFID reader device, which captures radio frequency waves from the RFID tag and transfers data wirelessly. Scanning data is as simple as bringing the card close to the RFID reader. A relay is an electronic component that operates on the principle of electromagnetic induction. When a conductor is energized by an electric current, a magnetic field forms around it. Figure 3 (c) shows the relay module, commonly used as a switch to operate electronic equipment such as lights, electric motors, and other devices with ON/OFF control. The microcontroller processes the sensor output values to determine the commands sent to the relay [4].




| PIN LABEL | |
|---|---|
| **Relay1** | **ESP** |
| GND | GND |
| VCC | 3.3V |
| IN1 | GPIO05 |
| | |
| **Relay2** | **ESP** |
| GND | GND |
| VCC | 3.3V |
| IN2 | GPIO04 |

| PIN LABEL | |
|---|---|
| **MFRC522** | **ESP** |
| RX | GPIO2 |
| SCK | GPIO14 |
| MOSI | GPIO13 |
| TX | GPIO12 |
| RST | GPIO0 |
| GND | GND |
| VCC | 3.3V |

**Figure 2.** Wiring Diagram of the Keyless Starter




(a) (b) (c)

**Figure 3.** (a) NodeMCU ESP8266 with Pin Out, (b) RFID MFRC522, and (c) Relay 2 Channels

The design of this system utilizes two software tools: Arduino IDE and Blynk. The NodeMCU ESP8266 is programmed using the Arduino IDE software, enabling it to receive input from the sensor and subsequently control the relays. Figure 4 illustrates the flowchart for scanning RFID and activating the relays. Meanwhile, Figure 5 displays the code for the Keyless Starter in Arduino IDE. The code begins by including the necessary libraries and defining and initializing various variables. The void setup() function is used to declare pin modes (INPUT or OUTPUT), initialize libraries, and it runs only once at the start. In contrast, the void loop() function is designed to execute and repeatedly run the program. The motorcycle's engine will turn ON if the RFID is scanned twice, resulting in both relays being set to HIGH.

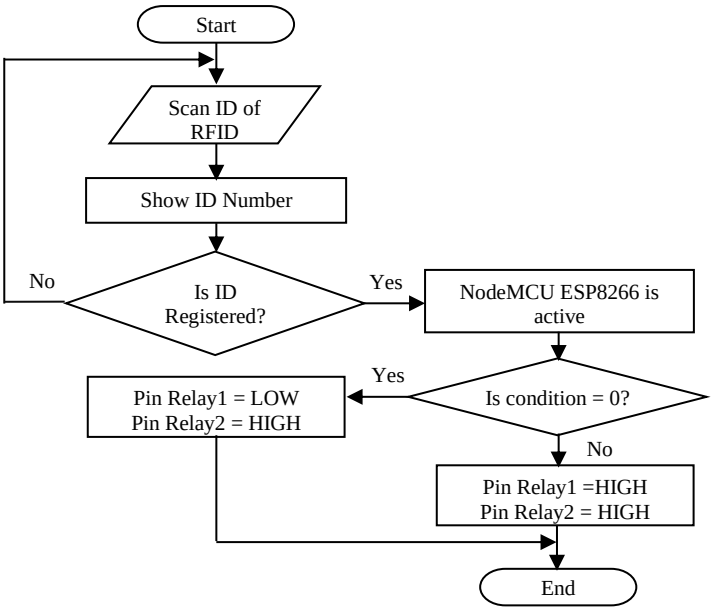



**Figure 4.** Flowchart for scanning RFID and activating the relays

```
#include <SPI.h>
#include <MFRC522.h>
#include <BlynkSimpleEsp8266.h>

#define SS_PIN 2
#define RST_PIN 0
MFRC522 mfrc522(SS_PIN, RST_PIN);
int pinRelay1 = 5;
int pinRelay2 = 4;

char auth[] =
"JBhMO75yOmBrbX5VU9ZxUD2hE5E29b1l";
char ssid[] = "JERO GEDE";
char pass[] = "yuaka207567";
int kondisi;

void setup()
{
 Serial.begin(9600);
 Blynk.begin(auth, ssid, pass);
 SPI.begin();
 mfrc522.PCD_Init();

 pinMode(pinRelay1, OUTPUT);
 pinMode(pinRelay2, OUTPUT);
 digitalWrite(pinRelay1, HIGH);
 digitalWrite(pinRelay2, HIGH);
 condition = 0;
}

void loop(){
 Blynk.run();

 // cek the new RFID card
 if ( ! mfrc522.PICC_IsNewCardPresent()){
  return;
 }

 // Select RFID card
 if ( ! mfrc522.PICC_ReadCardSerial()){
  return;
 }

 // Showing ID of RFID card on Serial
Monitor
 Serial.print("UID:");
 String content = "";
 byte letter;
 for (byte i = 0; i < mfrc522.uid.size; i++){
  Serial.print(mfrc522.uid.uidByte[i] <
  0x10 ? " 0" : " ");
  Serial.print(mfrc522.uid.uidByte[i], HEX);

  content.concat(String(mfrc522.uid.uidByte
  [i] < 0x10 ? " 0" : " "));

  content.concat(String(mfrc522.uid.uidByte
  [i], HEX)); }

Serial.println("");
content.toUpperCase();

if (content.substring(1) == "04 6F 85 2A 18
 5B 80"){
 if (condition == 0){
  digitalWrite(pinRelay1, LOW);
  delay(4000);
  digitalWrite(pinRelay2, LOW);
  delay(3000);
  digitalWrite(pinRelay2, HIGH);
  condition = 1; }
 else if (condition == 1){
  digitalWrite(pinRelay1, HIGH);
  digitalWrite(pinRelay2, HIGH);
  delay(1000);
  condition = 0;
} } }
```

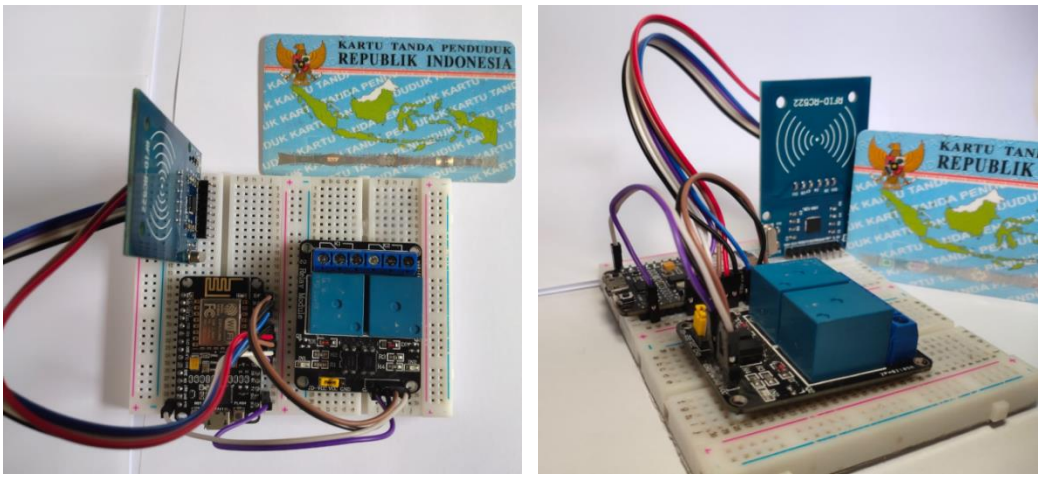
**Figure 5.** The code of the Keyless Starter in Arduino IDE

## Results and Discussions

Implementing this keyless starter tool involves three main stages: hardware development, application integration, and system installation. Each stage—hardware realization, application implementation, and system installation—has been meticulously executed to ensure seamless functionality.

### *Hardware Setup*

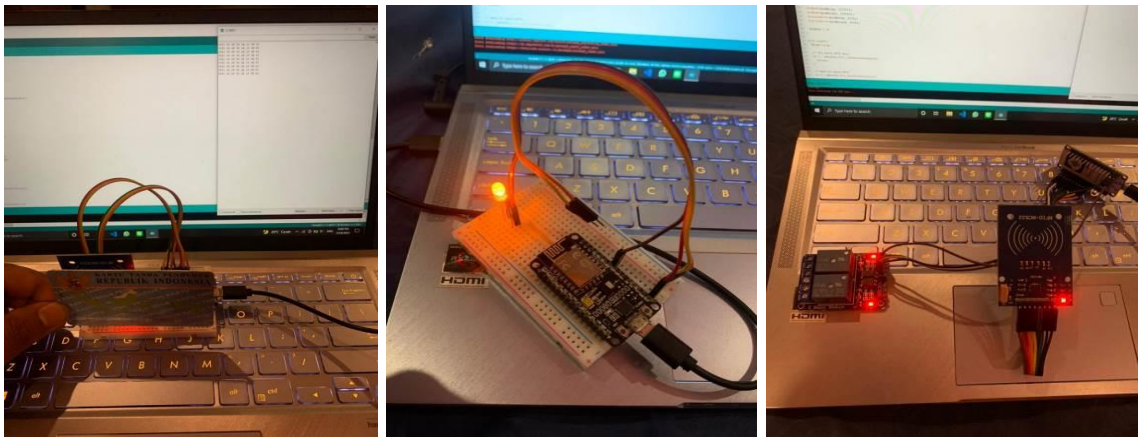
The components utilized in this keyless starter prototype adhere to the designed wiring diagram. Figure 6 shows the hardware implementation of the keyless starter in breadboard mode. In this setup, an electronic Indonesian Identity Card (e-KTP) serves as the RFID tag.




(a) (b)

**Figure 6.** Hardware realization, (a) top view, and (b) side view

Preliminary component testing is essential to verify proper functionality. Therefore, several tests were conducted, including an RFID sensor test. The RFID reader and cards serve as replacements for traditional keys to start the motorcycle engine. This involved testing with two RFID cards, each card tested twice to ensure reliability.



(a) (b) (c)

**Figure 7.** Preliminary test for (a) RFID, (b) NodeMCU ESP8266, and (c) Relay

Figure 7 (a) shows the testing of the RFID sensor. When the sensor reads a card, the card ID is displayed in the program's serial monitor, and the LED on the NodeMCU ESP8266 flashes to indicate successful reading. The results confirm that the RFID sensor functions correctly. Table 1 presents the RFID test data, showing consistent and accurate readings from the serial monitor across three tests.

**Table 1.** Initial testing of RFID

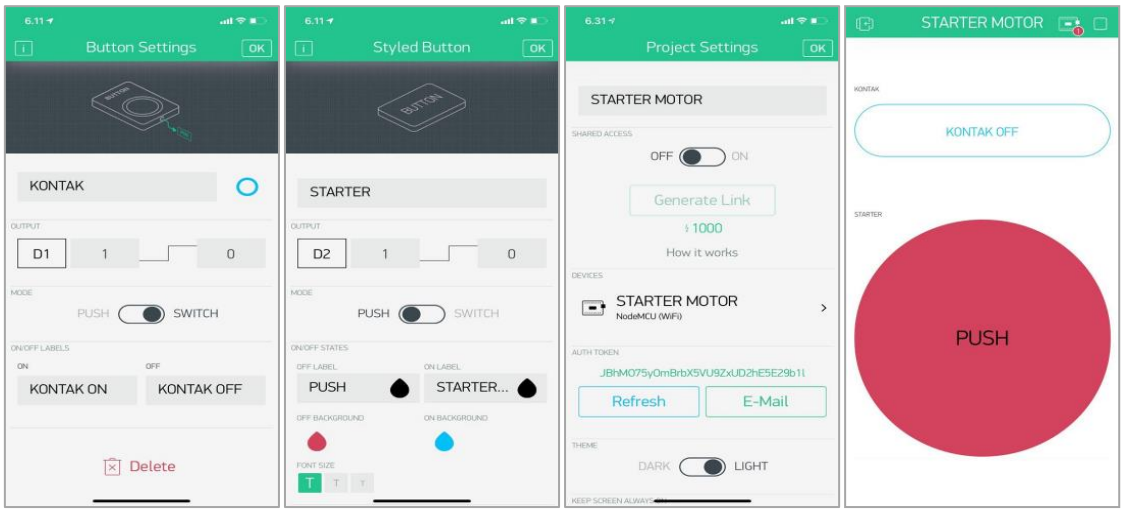
| No | RFID | Serial monitor | Result (twice) |
|---|---|---|---|
| 1 | 27 22 60 62 | Read | Correct |
| 2 | 27 22 60 62 | Read | Correct |
| 3 | 87 99 5A 62 | Read | Correct |
| 4 | 87 99 5A 62 | Read | Correct |

| | | | |
|---|---|---|---|
| 5 | 35 64 01 79 | Read | Correct |
| 6 | 35 64 01 79 | Read | Correct |

The NodeMCU ESP8266 is a control module tested by connecting its USB port to a laptop, as shown in Figure 7 (b). The testing involves using the Arduino IDE to upload a basic program designed to turn on an LED light. If the LED lights up successfully, it confirms that the ESP8266 module is functioning correctly. A relay is an electronic component that operates on the principle of electromagnetic induction and is commonly used for control in various devices. Figure 9 (c) depicts the relay testing process. During this test, the relay functioned correctly, as evidenced by the light of the LEDs on inputs 1 and 2, along with an audible clicking sound from both relays.

## *Application Setup*

The application integrated into this tool utilizes the Blynk platform, compatible with both Android and iOS. Designed as an alternative to key cards, this application enables motorcycle activation remotely via Wi-Fi, with a range of approximately 10 meters. Figures 8 (a-c) display the Blynk application's setup and interface, featuring indicators for ON/OFF status and a starter button depicted in Figure 8 (d).

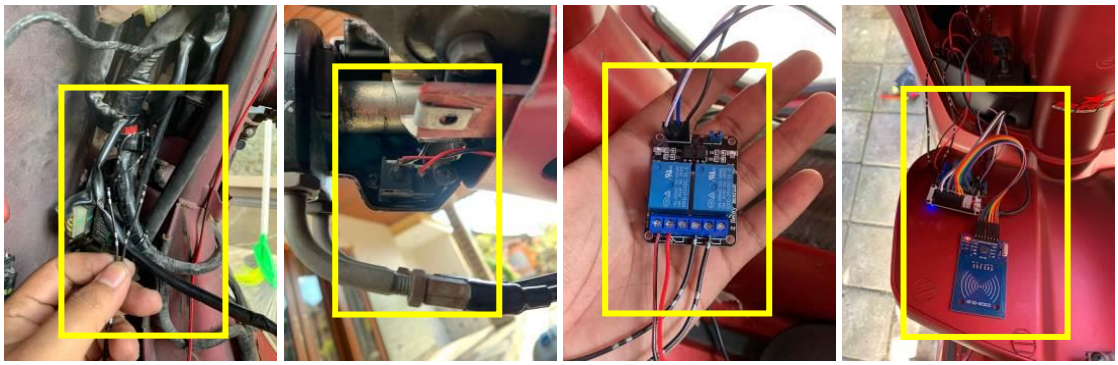



(a) (b) (c) (d)

**Figure 8.** a) Button Setting, (b) Styled Button, (c) Project Setting, and (d) The Starter App

## *System Installation and Testing*

The installation of the tool on the motorcycle involves four steps: (1) connecting the cable to the ignition socket, (2) connecting the cable to the motor starter, (3) connecting the cable to the relay, and (4) installing the tool in the front trunk of the motorcycle. When accessing the ignition socket, identify the two wires and connect them to the cable already linked to input 1 on the relay. Similarly, for the motorcycle's starter, connect its two wires to the starter motor cable and then to input 2 on the relay. Figures 9 (a) and (b) illustrate the wiring on the ignition socket and the starter, respectively.



(a) (b) (c) (d)

**Figure 9.** The Instalation of Keyless Ignition and Starter on the Motorcycle

Connect the red wire from the starter motor to relay input 2 and the black wire from the ignition key to relay input 1. Figures 9 (c) and (d) show the wiring on the relay module and the installation of the tool in the front trunk of the motorcycle. To prevent water splashes, the RFID sensor, NodeMCU ESP8266, and relay are installed in the front trunk, positioned close together for more accessible wiring. Finally, connect the NodeMCU ESP8266 to the motorcycle's built-in USB port using a USB type-A cable.

After installing the tools on the motorcycle, an overall test was conducted. The test focused on starting the motorcycle using either the tag card (e-KTP) or the Blynk application. The system operates as follows: when the e-KTP card is tagged to the front trunk of the motorcycle, as shown in Figure 10 (a), the RFID sensor reads the registered card. Relay 1 then automatically activates the motor contacts. There is a 4-second delay before Relay 2 engages to start the motor starter. After this delay, the motor starts automatically, as depicted in Figure 10 (b). In this case, the RFID sensor and ESP8266 might need a brief moment to process the next command after the first relay activation. The delay ensures smooth and error-free processing. This delay can also prevent multiple actions from occurring too quickly, which might confuse or inconvenience the user. It can also serve as a brief period for the system to provide feedback (e.g., via an LED indicator or a sound) to the user that the first action has been completed, enhancing the overall user experience.

(a) (b) (c) (d)

**Figure 10.** Overall Final Test using eKTP (a & b) and Blynk Application (c & d)

The ON/OFF test was conducted three times. Table 2 presents the test results using the e-KTP, while Table 3 displays the results using the Blynk application. To turn off the motor, simply tap the card in the same location as when turning it on. Table 4 presents range testing using Blynk to ON/OFF the engine.

**Table 2.** ON/OFF testing result using eKTP

| No | e-KTP | Engine | Result |
|---|---|---|---|
| 1 | Read | ON | Correct |
| 2 | Read | OFF | Correct |
| 3 | Read | ON | Correct |
| 4 | Read | OFF | Correct |
| 5 | Read | ON | Correct |
| 6 | Read | OFF | Correct |

**Table 3.** ON/OFF testing result using Blynk

| No | Contact | Starter | Engine | Result |
|---|---|---|---|---|
| 1 | ON | ON | ON | Correct |
| 2 | ON | ON | ON | Correct |
| 3 | ON | ON | ON | Correct |
| 4 | OFF | - | OFF | Correct |
| 5 | OFF | - | OFF | Correct |
| 6 | OFF | - | OFF | Correct |

**Table 4.** Range testing result using Blynk

| No | Range | Contact | Starter | Engine |
|---|---|---|---|---|
| 1 | 1 Mtr | ON | ON | ON |
| 2 | 3 Mtr | ON | ON | ON |
| 3 | 5 Mtr | ON | ON | ON |
| 4 | 10 Mtr | ON | ON | ON |
| 5 | 11 Mtr | ON | ON | OFF |
| 6 | 12 Mtr | ON | ON | OFF |

The next test involved the Blynk application, which is configured with two controllers: the Contact Button and the Starter Button. The Contact Button is used to turn the ignition on and off, while the Starter Button starts the motor. To operate, press the ON ignition button to activate the motor ignition, then press the Starter Button to start the motor. To turn off the motor, press the OFF button. Figures 10 (c) and (d) show the motor's ON and OFF conditions, along with the Blynk application's interface.

After comprehensive testing, the tool proved to operate correctly. This proposed system provides enhanced security for the motorcycle, reducing theft attempts. Future improvements include adding a GPS module to capture the motorcycle's geolocation for further analysis [15].

## Conclusion

This study proposes a motorcycle keyless starter using the NodeMCU ESP8266 as a microcontroller. The NodeMCU controls dual-channel relays that connect to the motorcycle's ignition and starter. The motorcycle can be started by either tapping a registered e-KTP card to the RFID reader or using the Blynk application on a smartphone via Wi-Fi. The application enables motorcycle activation remotely via Wi-Fi, with a range of approximately 10 meters. Meanwhile, there is a 4-second delay to start the motor starter using e-KTP. The test results indicate that this system effectively enhances motorcycle security and reduces theft attempts. Future improvements include adding a GPS module to capture the motorcycle's geolocation, allowing for analysis of human mobility dynamics and patterns.

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# Food Journal: An application for allergy early detection

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**Abstract:** Allergies are now increasingly common, due to public awareness and lifestyle changes. Although antibody tests and skin pricks can detect allergies, their accuracy is not always 100%, causing some cases of false negatives. Observing the reactions caused by food is an alternative approach, but people often forget the food they consume, especially if the allergic reaction is indirect. Therefore, tools are needed to record foods and reactions, allowing traceability to undetected allergy triggers. This study is applied research that aims to develop a prototype application for recording daily food and tracking the history of eating activities based on the allergy symptoms entered. The software development method used is the Agile method with the Scrum framework. The Scrum framework is used considering that the development of this application requires speed in its provision, and is susceptible to change, so flexibility in development is an absolute must. The software testing was conducted by User Acceptance Testing (UAT) to ensure it meets the user's needs and requirements. The UAT results are ease of use 3.8, functionality 3.99, user interface (UI) design 3.8, utility 4, and support and help 4. UAT results indicate that the ease of use and UI design have the worst scores and need to be improved, while the utility and support have the best results.

**Keywords:** Food Allergy, Food Journal, Food Tracking, Web-Based Food Tracking

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## Introduction

Allergy is a reaction of the human immune system to substances that enter the body which are considered dangerous substances and are known as allergens [1]. When a person is exposed to an allergen, the immune system responds by producing antibodies to protect itself [1]. This response causes various abnormal symptoms ranging from mild symptoms such as itching and sneezing to more serious reactions such as rashes, flatulence, diarrhea, inflammation, shortness of breath, and even life-threatening anaphylaxis [2]. High-intensity exposure to allergens and continuous abnormal reactions can disrupt the body's organ systems and thus affect a human's quality of life [3], therefore it is very important to control it by recognizing the triggers for allergies.

There are various types of allergy triggers such as drugs, animals, pollen, dust, mold, including food. The most common types of food that can cause allergic reactions are cow's milk, eggs, nuts, shelled seafood, various types of shellfish, and even fish [3]. These various foods are then converted into food substances, including protein. It is a protein that often causes allergic reactions in some people who have high sensitivity [4]. The appearance of allergy symptoms after food is introduced does not always indicate that a person is suffering from a food allergy, but can also be caused by other health conditions such as intolerance or sensitivity to certain foods [4].

Regardless of the cause, whether allergies, intolerance, or sensitivity, all of them can affect the human immune and digestive systems, which ultimately if disturbed can disrupt their quality of life [3]. Especially if this happens to babies. Babies aged 6 months and over begin to need various types of food to grow and develop, however, if exposure to allergens occurs continuously it will of course harm their growth and development [5]. When allergic reaction symptoms appear, immediately following the treatment recommended by the doctor to manage the symptoms is

important, but avoiding exposure to the triggering food must still be recommended continuously [6].

There are various tests to find out what type of allergy a person has, such as the Skin Prick Test (SPT) IgE Atopy test, or IgG Food Sensitivity. Both options require consumers to be taken to a laboratory so they cannot analyze anywhere and anytime [7] and of course, require quite a lot of money. As an alternative, a food introduction trial can be carried out for babies [8] or an elimination diet for children and adults, followed by observing allergic reactions that appear after the food is given [9]. Screening can be chosen to carry out early detection [10]. Food trials, continuous observation, and recording need to be carried out to make it easier to conclude the triggers for reactions, therefore it is important to record a track record of food consumption because excessive avoidance is not always wise [11].

Daily food recording related to diet is preferred if using electronic devices [12]. Currently, there are many applications and research related to food recording, such as self-monitoring calcium consumption applications [13], mindful eating [14], food monitoring for people with eating disorders [15][16], obesity management [17], macronutrients and food calories [18][19][20], healthy eating patterns for adolescents [21], toddler feeding [22]. One application that records food and the reactions it may cause is TummyTrials. This application is specifically for sufferers of irritable bowel syndrome (IBS), where users will try to check the typical symptoms of IBS (stomach pain, bloating or gas, hard defecation, watery defecation, infrequent defecation, frequent defecation, urge to defecate) when consuming foods suspected to be triggered (caffeine, gluten, sorbitol, lactose) [23]. Several applications have integrated the use of artificial intelligence in their applications for the recognition of user-uploaded food photos [17][18][19][24].

Some studies have observed several popular diet applications. Research by Franco et al, [25] found that 9 of the 13 most popular apps had a food diary feature and one of them connected users with health professionals. All apps use text search and barcode scanners to input food. Mostly apps for weight management. None of the apps have a decision engine capable of providing personalized diet advice. Research by Ferrara et al [26] examined the seven most widely used diet apps, and none of them provides tracking features for emotional factors that may be related to dietary patterns. All apps focus on calorie counting and macronutrients.

Existing diet apps are often designed for general weight loss and are not tailored to specific risk factors [27]. Most people who try these free mobile apps to monitor their diet, do not continue to actively use them and those who do may already be healthy eaters [28]. The main challenges that users face include the interface, search options (for food), portion sizes, and reminders when using these applications [29]. Providing recommendations is also required in applications [30].

Based on previous research, it is clear that no food tracking application specifically focuses on food allergies or sensitivities. Several studies have suggested the need for applications for specific risk factors [27] and recommendations [30]. The study by Helander et al [28], suggested improvements to the search and interface. For this reason, this research aims to build an application of daily food tracking applications. The application can record all foods and the symptoms of reactions felt, as well as track foods eaten up to 3 days previously to provide recommendations for possible food causes of allergies so that users can be more aware and make better observations of certain foods that are suspected to trigger allergies. This application is mainly useful for users who are on a food-elimination diet to observe allergic reactions in their bodies to newly introduced or reintroduced foods.

## Methodology

This study examines objects in the form of using the Scrum framework in developing food journal applications. The data in this study are collected through a literature review and questionnaire. The data collected by the literature review includes the food tracker application that already exists, the features of the application, and what improvement is needed. The questionnaire was needed to conduct end-user testing.

Scrum is made to be able to develop software flexibly and quickly. The main step was: pre-sprint, sprint, and final testing. Figure 1 shows the brief step of this framework.

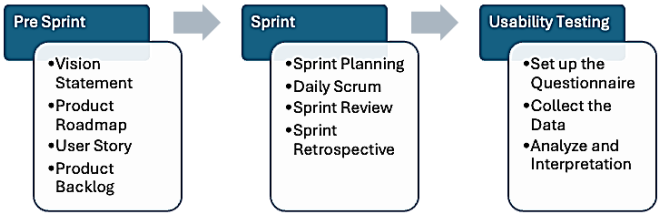


**Figure 1.** Food journal application development using SCRUM

The pre-sprint stage is the initial stage before developers start building applications. First, a vision statement will be carried out to provide a summary description of the project objectives, which will help the development team to stay focused on its path. Next is to create a product roadmap which is the initial timeline for working on the main features and is usually done by the Product Owner. Next, user needs are collected to create features. This part is called the story. Stories are usually created by the Product Owner based on user needs. All stories will form the Product Backlog. Projects can be carried out without having to wait for 100% product backlog, and the product backlog can also change throughout the project journey.

When the product backlog has been formed, the next step is entering the sprint period. Each module will be carried out in a short sprint, which in this research is seven days. In this sprint planning, the tasks and working hours of each personnel involved in the project are also regulated. In development with Scrum, daily meetings are always held to discuss the progress of the tasks of each work team and determine what to do next. Stand-up meetings do not have to be attended by all team members, but only members who are interested in the current sprint. A Sprint Review is carried out every time a sprint is completed, namely by conducting a demo with the client. In this way, clients can find out about project progress and can provide input or desired changes. The Sprint Retrospective stage aims to carry out an evaluation based on the results of the review that has been carried out. The results at this stage can be in the form of continuing to the next sprint or fixing problems that still exist in the current sprint. All changes will be recorded in the Product Backlog [31].

The last step was the final testing. Although in sprint review, the testing is already conducted by the client, it is very important to do final testing involving the end user. The testing was conducted using the System Usability Scale (SUS). The first step was to set up the questionnaire. The data was collected from 30 users and the the result was interpreted.

## Results and Discussions

### *Results*

The pre-sprint stage resulted in nine product backlogs as shown in Table 1. There are three user roles identified: guest (unregistered user), member, and system administrator. As implied in Table 1, each user has a role in the application. Each product backlog becomes a single sprint, which is conducted every seven days.

**Table 1.** The user backlog

| Backlog | Item | User role |
|---|---|---|
| User management | Guest can show general information, but to use a food journal feature, they must be registered into the application. The authentication process is very important to ensure that only authorized users can access records. | Guest: to register<br>Member: login<br>Administrator: login |
| Food and nutrition information | Users can read and search the information about food and nutrients. The information must be up to date. | All Users: read and search<br>Administrator: add or update information |
| Article management | Users can read and search the general information about food allergy/sensitivity/intolerance. The information must be up to date. | All Users: read and search<br>Administrator: add or update information |

| | | |
|---|---|---|
| Food journaling | Members can input daily food consumption, including the amount and time. The system must enable the member to input the complete ingredients of certain food. For the same kind of food that has been recorded in the system, no need to reinput the ingredients. | Member: Input and read the daily journal |
| Symptom management | Members can input the symptoms they feel at a certain time. The application must enable the member to track certain symptoms and show all the food they consume for a range of three days before each symptom and rank the food based on frequency/amount. For additional information, the sleep quality, mood, Bristol chart, and daily notes are also shown. | Member: input and search symptom, view the information related to the time of the symptom. |
| Mood management | Members can input the mood they feel at a certain time. | Member: input |
| Bristol stool management | Member can input the stool based on the Bristol Scale at a certain time. | Member: input |
| Sleep management | Member can input the quality and time of their sleep | Member: input |
| Daily notes management | Members can input other information, such as prescription drugs consuming | Member: input |

The main feature of the application is food tracking related to certain symptoms based on the time. The page of symptom searching is shown in Figure 2. For example, the member enters the keyword "pusing" (headache) in the search bar. The application will respond by showing the appropriate symptom, their frequency, and the specific time the symptom occurs. Users can view all the food they consumed starting from 3 previous days of the symptom and the foods are ordered from the most frequently eaten.

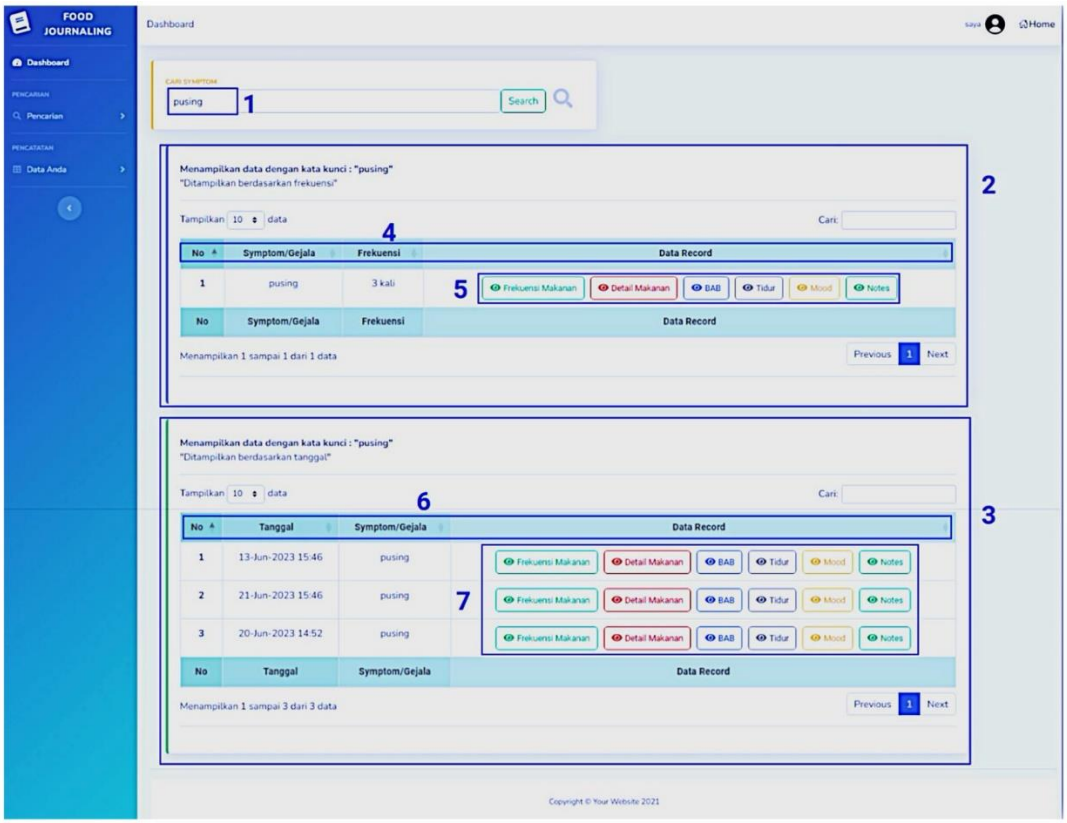


**Figure 2.** Symptom search result

User Acceptance Testing (UAT) was conducted to make sure the application met the user's needs and requirements. The are 22 respondents to the UAT questionnaire. The UAT measures six dimensions and 14 questions as shown in Table 2.

**Table 2.** The User Acceptance Test (UAT) result

| Dimension | Question | Score |
|---|---|---|
| Ease of Use | You find the application easy to use. | 3.9 |
| | The navigation of the application is intuitive and easy to understand. | 3.7 |
| Function-ality | The food logging feature in the application works well. | 4 |
| | The mood logging feature in the application works well. | 4 |
| | The symptom logging feature in the application works well. | 4 |
| | The search feature for meal history based on symptoms helps you find previous records. | 3.95 |
| User Inter-face De-sign | The interface design of the application is attractive and visually pleasing. | 3.9 |
| | The layout of elements in the application is neat and well-organized. | 3.7 |
| Perfor-mance | The application functions smoothly without technical issues. | 3.9 |
| | The response time of the application is quick when logging food or searching meal history. | 3.9 |
| Utility | The application helps you manage daily food logging. | 4 |
| | The meal history search feature is useful for monitoring eating patterns. | 4 |
| Support and Help | The user guide and support in the application help you resolve issues. | 3.95 |
| | You feel adequately supported when encountering problems with the ap-plication. | 4.05 |

## *Discussions*

The Food Journal application developed is primarily aimed at logging an individual's eating history and various symptoms experienced daily. Through the tracking feature or searching for specific symptoms, users can view the rankings of foods consumed over the last 3 days when the symptom was felt. This feature differentiates this application from other existing ones.

From the results of the user acceptance testing (UAT) shown in Table 2, the average scores are as follows: ease of use 3.8, functionality 3.99, user interface (UI) design 3.8, utility 4, and support and help 4. There are two dimensions with the lowest scores: ease of use and UI design. A good user interface should ideally facilitate user interaction with the system. This indicates that improvements are needed in UI design to enhance usability. Improved ease of use will affect user experience and the sustainability of application use. Therefore, addressing UI issues is crucial. Dimensions that show benefits and usefulness to users are functionality and utility. The UAT results show that the functionality score is 3.99, which is nearly good, while the utility score is 4, indicating good. This suggests that users find the features provided useful and functioning as well as expected. Additionally, support and help, in the form of a user manual, also received a good score.

## Conclusion

From the study that has been done, it can be concluded that the use of the Scrum framework can build an online learning application. The use of this framework fits perfectly with the characteristics of users who have not been able to clearly and in detail define their needs. The existence of deliverables that are directly given and can be used by users directly after a sprint is executed can explore more data on user needs. The User Acceptance Testing (UAT) determines six criteria: ease of use 3.8, functionality 3.99, user interface (UI) design 3.8, utility 4, and support and help 4. The lowest scores are in the UI design and ease of use dimensions. UI design and ease of use are closely related; the easier a UI is to understand, the better the ease of use. This indicates that these two dimensions need attention and improvement. The best scores were obtained in the utility support and help dimensions, while the functionality dimension has a score of

3.99 that quite good. These results show that the system is considered good at meeting user needs. The further study focuses on improving the ease of use and user experience, as well as additional features for personal allergic food warning systems.

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# Ontology-based data framework for the digital preservation cultural heritage: A case of *Subak*

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**Abstract:** Cultural heritage is increasingly fading due to the influence of globalization and social changes that shift traditional values. Digitalization is critical to addressing the degradation of cultural heritage knowledge by enabling more accessible storage and documentation and facilitating preservation and education efforts for future generations. *Subak*, as a unique traditional agricultural system in Bali, Indonesia, has a wealth of valuable knowledge and culture, but it is still scattered and unstructured. An ontology-based Knowledge Management System is designed to capture, organize, and utilize knowledge within a domain using ontologies as a fundamental component. Ontologies explicitly represent knowledge by providing meaning, properties, and relationships with related concepts. This paper proposes data modelling with the Ontology Development framework for the knowledge base. The methodological framework consists of knowledge externalization, including identifying and collecting knowledge based on data modelling through interviews and observations. The second steps are modelling and development of ontology, based on the knowledge that has been previously disclosed, including the hierarchical structure, properties, and relationships that form the knowledge base. The third stage is the Implementation and evaluation, which involves evaluating the quality of ontology using onto metrics and implementing the ontology into the KMS. The result of this study is data modeling for the knowledge base and the Ontology Development framework. The data modelling is a form of data mapping based on a combination of traditional philosophy and modern management principles that underlie Subak activities and artefacts, namely Tri Hita Karana, Desa Kala Patra, and POAC. The proposed framework can be a reference in developing new ontologies from scratch on unstructured cultural heritage data.

**Keywords:** Cultural heritage, Digital preservation, Knowledge Externalization, Ontology Development, Ontology Evaluation

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## Introduction

Digitizing cultural heritage has become a significant concern for researchers and practitioners [1][2][3][4][5][6][7][8]. Cultural heritage is not just about history but about identity, shaping origins, informing current conditions, and guiding the future. This heritage is a source of pride and an irreplaceable basis for human unity. However, as modernization progresses, there is a real fear that these cultural treasures will be lost. Many efforts have been made to digitize cultural information using video content, photos, museums, and digital documents. However, contextual information and tacit cultural practices have not yet been fully accommodated in the process [4]. Tacit knowledge refers to knowledge derived from personal experience, deeply ingrained within an individual, difficult to articulate and convey, and synonymous with practical knowledge [9]. This knowledge is often embedded in social interaction and direct experience, making it difficult to represent it explicitly digitally. A large amount of cultural knowledge is kept secret and shared exclusively within the community. Therefore, a new digitalization approach must incorporate both explicit and tacit aspects of cultural information.

The digitalization of cultural information should increase ease of access and knowledge sharing [10]. Through digitalization, cultural knowledge can be presented in various formats so

that it can be easily accessed. This opens up opportunities to disseminate knowledge among individuals, groups, and communities. Therefore, the digitization of cultural information has great potential to enrich and preserve cultural diversity, encourage intercultural dialogue, and increase understanding and appreciation of valuable cultural heritage for future generations [11]. The digitization of cultural information is essential for managing the risks of losing valuable knowledge [1]. Converting cultural information into digital format makes it durable and easily accessible, minimizing the risk of degradation [12], damage, or loss due to various factors. Digitalized cultural data is valuable for strategic planning, policymaking, and effective cultural heritage management, providing a foundation for sustainable preservation efforts. Knowledge Management System (KMS) [13], a field of science that aims to capture, organize, disseminate, and utilize knowledge, has the potential to be vital in maintaining the sustainability and accessibility of valuable traditions of cultural heritage more effectively [14]. In a KMS, information is collected, stored, and organized using information technology so that users can access and use it efficiently.

Currently, many KMS are developing based on ontology [3], [8], [15], [16], [17], [18]. Ontology-based KMS uses a formal semantic structure to represent knowledge and relationships between entities. Ontologies enable a deeper understanding of the meaning and context of information, thus facilitating more informed decision-making and analysis processes [19]. By leveraging ontologies, KMS can become more competent in providing users with relevant information and deeper insights. Ontology is a formal, evolving knowledge model that defines entities, attributes, relationships, and rules within a domain. It ensures semantic consistency, supports knowledge discovery and reasoning, and facilitates interoperability, thereby serving as the core structure for knowledge creation, storage, retrieval, and application within a KMS [18]. Ontology is the basis for developing intelligent applications and systems that can produce a deeper understanding and consistent interpretation of various aspects of knowledge, one of which is applied in cultural preservation [6]. Based on the literature review, no research has discussed the development of Ontology-based *Subak* KMS, which represents the agriculture Balinese culture and tradition. This project aims to increase the Balinese and the younger generation's understanding of essential aspects of knowledge and culture with the Ontology-based KMS *Subak* in the form of an online digital portal system. Several forms of KMS cultural heritage have been developed in various countries. The South African government has developed the Indigenous Knowledge System [20] to formally protect and promote their traditional practices, knowledge of natural medicines, and oral history. The Korean Cultural Atlas [21] has been created, serving as a digital platform to map and record the nation's various cultures, languages, and traditions.

This research is the initial stage of a digital project that aims to uncover and present complex knowledge through a digital platform in order to benefit many individuals who have a deep interest in Balinese culture and traditions. This paper presents a framework for structuring and categorizing knowledge to facilitate preserving, archiving and disseminating distinctive cultures by leveraging people's expertise and understanding of their cultural heritage. The challenge in digitizing cultural heritage is preserving non-material information, such as historical narratives and cultural practices. UNESCO has recognized that such information is fragile and prone to being forgotten, making the digitization of cultural knowledge essential for preservation [22]. Bali, renowned as a global tourist destination, owes its appeal to its distinctive culture, encompassing activities and practices, traditional music, dance, painting, and stunning natural landscapes. The complexity of Balinese cultural knowledge [23] necessitates significant effort to model it, even for cultural experts and local communities. Much of this knowledge is embedded in tacit forms and integrated into the everyday practices and traditions of Balinese life.

One interesting cultural practice in Bali is *Subak*, an irrigation and farming activity rooted in Balinese culture. Moreover, in the lack of detailed documentation on Balinese culture, especially the Balinese *Subak*, this study becomes even more challenging and meaningful. Furthermore, the diverse and non-standard complexities of *Subak* practices emphasize the importance of accurately understanding and capturing this information and integrating it into a suitable system.

## Methodology

### *Ontology Modelling*

Ontologies have been developed based on various research methodologies in various cultural preservation domains. Most of the ontology of cultural preservation was formed from

scratch [24]. This causes the research methodology to be more adapted to the characteristics of data collection challenges and the scope of the knowledge domain. The challenges of data collection in cultural preservation often include data sources that are scattered across multiple media, languages, and formats. In addition, a deep understanding of the cultural domain is required to recognize that cultural data is deeply rooted in local traditions and interpretations, which require careful handling to maintain accuracy and authenticity in representing aspects of intangible heritage. Previous research conducted a literature study to formulate a research methodology for developing the *Subak* ontology as a stage of this research [25]. The system in this study is designed and developed using the Ontology Development Methodology (ON-ODM), which has been adapted to the *Subak* knowledge domain.

Ontology modeling is needed to represent knowledge. Ontology modeling is a framework for analyzing relationships between classes and their properties. CIDOC-CRM is an ontology modeling developed to harmonize the domains of libraries, museums, archives, and cultural data sets. It has now defined 99 classes and 198 properties [26]. In this research, CIDOC-CRM is only used as a modelling reference; many adjustments have been made considering that the complexity and characteristics of the specific *Subak* domain are very different from the framework offered.

Ontology evaluation involves external validation and internal consistency. External validation begins with selecting CQs to become Golden CQs, which are then implemented using SPARQL queries and modelling guidelines as references to validate ontology modelling. Experts will confirm the validity of fulfilling sufficient knowledge that SPARQL can find. If it is deemed insufficient, enriching the ontology is necessary. Internal consistency checks the ontology's syntactic correctness and internal consistency using the reasoning program (reasoned) included in Protégé. Ontology Metrics OntoQA [27] are used to measure ontology consistency. Considering that knowledge continues to develop, knowledge adequacy is addressed by continuous and structured knowledge enrichment.

## *Proposed Model*

The proposed model Figure 1 based on previous study [25], involves three activities: 1) Knowledge externalization, 2) Modelling and Development and 3) Implementation and Evaluation. Knowledge will continue to be completed in the enrichment stage to ensure sufficient knowledge. Knowledge externalization ensures that implicit and explicit knowledge in the cultural domain can be identified and systematically structured. Furthermore, Modelling and Development enable the knowledge to be translated into an organized ontology structure, while Implementation and Evaluation ensure that the ontology functions well in real applications and is relevant to the purpose of cultural preservation.

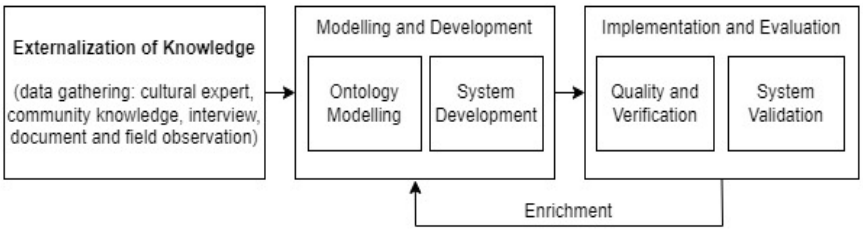


**Figure 1.** Proposed ontology development methodology

## Results and Discussions

The knowledge domain must be determined before developing ontology-based knowledge; this is to provide limits to the extent to which the scope of knowledge will be accommodated and focused. This step is followed by determining the objectives of ontology formulation and the stages of developing the ontology.

To build an inclusive and comprehensive Balinese Subak ontology, a structured and collaborative approach needs to be applied so that all aspects of Subak culture and knowledge

are represented. The first step is to conduct an in-depth identification of the concepts and relationships in the Subak system, such as the principles of Tri Hita Karana, irrigation practices, and agricultural land management, which can be broken down into more detailed sub-categories. Next, involve various stakeholders, such as Subak farmers, community leaders, cultural experts, and academics, to collect tacit and explicit knowledge that may not be formally documented but plays a vital role in Subak's sustainability. Participatory mapping and focus group discussions with stakeholders can ensure that the practical knowledge and social values underlying Subak are documented in the ontology.

Subak knowledge is not only documented but also hierarchically structured and connected in certain relationships. This procedure allows aspects of tradition, environmental values, and Subak ritual practices to be integrated into a digital system. The resulting ontology supports the interoperability of cultural knowledge, so that cultural data such as Subak can be shared, analyzed, and utilized by various parties at the international level for research, education, and culture-based tourism. The Subak ontology can be a model for other cultures to overcome the challenges of digitalization and preservation, while maintaining the authenticity and richness of local values within the global ecosystem.

## *Knowledge Domain*

Bali is an island that is part of Indonesia's country and is known as one of the provinces with the smallest area. Balinese cultural heritage is preserved by carrying out daily activities and religious rituals to maintain the continuity of tradition. The next generation learns and accepts this heritage through experience at every stage of local Balinese cultural activities. The foundation of Balinese culture is found in the structure of traditional Balinese society, including *Desa Adat* (also known as *Desa Pekraman*), *Banjar*, and *Sekaa*. Although the trend of modernization has emerged, religious ceremonies, which are an integral part of the thoughts and views of the Balinese people, are still upheld at the same level of relevance and importance from the past to the present. The traditional agricultural system exclusive to the island of Bali, namely the *Subak* System, plays a central role in the structure of Balinese society and acts as an irrigation method that is still carried out from generation to generation.

*Subak* is a traditional irrigated farming system unique to the island of Bali, Indonesia, and forms the core of Balinese life. The *Subak* system is based on the principle of Tri Hita Karana, a philosophical concept about the three causes of human happiness that can be achieved by maintaining harmony between the elements of *Parhayangan* (God), *Pawongan* (humans), and *Palemahan* (environment) [23]. In *Subak*, farmers respect and perform various religious ceremonies, ensure the sustainability and fertility of nature through fair and sustainable water management, and promote mutual welfare by dividing the harvest fairly among *Subak* members. In addition, *Subak* is also related to the concept of Desa Kala Patra, namely the view that the village is a reflection of the wider cosmos. *Subak* has an essential role in reflecting and implementing the principles of Desa Kala Patra by setting the time and planting season based on the layout of the Hindu calendar and astronomical order. Farmers consider the right moment to carry out agricultural processes and religious ceremonies based on natural cycles, creating a balance between human activities and the universe. Those activities show that *Subak* has implemented modern management principles in planning, organizing, actuating, and controlling (POAC) activities. UNESCO recognized *Subak* as a World Cultural Heritage in 2012 for its role in preserving cultural values, sustainable agricultural practices, and social harmony on the island of Bali [28]. Even though faced with the challenges of modernization and urbanization, *Subak* continues to survive and adapt to changing times so that it remains a valuable cultural heritage and becomes an essential part of the identity and life of the Balinese people.

Cultural heritage is a cultural heritage from the past in the form of physical artefacts (cultural assets) and intangible attributes that are still used for the lives of today's society and then passed on to future generations in a sustainable manner. To move into the digital era, cultural heritage institutions such as galleries, libraries, archives, and museums have begun to identify the need to digitize their collections and make them available online [29]. The most important goal of cultural heritage KMS is to make cultural heritage knowledge accessible, further developed, and passed on to future generations. In addition, cultural information has an important role as a facilitator of collaboration because it involves various interrelated disciplines,

allowing students, researchers, teachers, and the community to explore and study cultural heritage [3]. Cultural heritage KMS includes sites, objects, and intangible objects with cultural, historical, aesthetic, archaeological, and scientific value for groups and individuals. KMS is not just about preserving information but also about optimizing the use of organizational knowledge. It involves the systematic management of the knowledge held by an organization to ensure that the knowledge is not only well stored but also well organized and easily accessible to members of the organization.

## *Externalization of Knowledge*

The initial phase in converting knowledge from tacit to explicit within the construction of the *Subak* ontology is called externalization. Currently, individuals possess tacit knowledge, such as farmers, community leaders, or *Subak* experts. This information is being transformed into explicit knowledge, organized and standardized based on ontology. The primary objective of this initial phase is to externalize knowledge and construct a fundamental ontology model that a computer-based system can utilize to enhance the process of searching and retrieving information about *Subak*. This phase can be conducted through direct interaction, interviews, observation, and also active engagement in *Subak* activities.

This tacit knowledge includes traditional practices, cultural values, ways of thinking, and understandings that are only sometimes easily expressed verbally. *Subak* knowledge is primarily tacit and transmitted through socialization processes (tacit-to-tacit) within the Balinese social system across generations. Therefore, representing this knowledge often involves using imagery, activities and other non-verbal methods that do not rely on formal language. However, the externalization of tacit knowledge remains one of the most challenging stages in the knowledge conversion process. An extensive literature review was conducted to develop the interview framework and identify critical issues related to *Subak*. The snowball sampling strategy was employed to facilitate the externalization of community-based tacit knowledge. In this method, participants are asked to recommend others relevant to the study, making it particularly suitable for research involving unfamiliar topics or complex phenomena. Each snowballing process, initiated independently by experts in specific groups, generates distinct networks of participants. The snowballing continues until data saturation is achieved, meaning no new information emerges, and participants begin to provide redundant responses.

A semi-structured interview was employed to collect data, enabling the researcher to address specific questions and topics. It also allows participants to offer additional insights and elaborate on any aspects of their experiences they consider relevant to the study [30]. The interview questions were organized into three primary categories: (a) the history of *Subak*, (b) the artefacts of *Subak*, and (c) the practices of *Subak*.

The stage of knowledge externalization is through three approaches: metaphors, analogies, and models [13]. The metaphor-based externalization method uses comparisons or metaphors to express tacit knowledge. Knowledge of water flow in nature can be used as a reference for understanding the concepts and functions of the *Subak* irrigation system, thereby assisting in designing an appropriate and more structured ontology structure. Furthermore, analogies can be used to describe how the *Subak* irrigation system functions by likening it to more familiar examples. For example, the *Subak* irrigation system is analogous to a modern water canal system. This analogy helps us understand the functions and mechanisms of the *Subak* irrigation system more quickly and clearly, thereby facilitating the representation process in ontology. The third approach is modeling, where a physical or digital model can show how the *Subak* irrigation system works, how the cropping pattern is carried out, and how other aspects of *Subak* interact. This model helps in visualizing knowledge about *Subak* in a more concrete and in-depth manner.

## *Modelling and Development*

Based on the interview result, we propose the *Subak* ontology-based data Framework as depicted in Figure 2. The framework is used for ontology modeling to explore, classify, and organize *Subak* knowledge. The ontology is designed using Balinese language representation, considering that many *Subak* terms are terms Balinese people use in their traditional lives. With this framework, the mapping of *Subak* knowledge is carried out by outlining the main principles of Balinese culture, namely Tri Hita Karana and Desa Kala Patra, as well as the application of

modern management, namely the POAC principle. Tri Hita Karana, a philosophical concept about the three causes of human happiness [23] which consists of (1) Universal (*Parahyangan*), namely the relationship with the creator of the universe, (2) the environment (*Palemahan*), namely the relationship with nature, and (3) humans (*Pawongan*) namely harmony between people. These three concepts are applied in *Subak* activities, where each stage of rice field management will begin with a religious ceremony (*Parahyangan* activities), starting from seeding, tillage, planting, and maintenance until harvest time arrives to preserve nature (*Palemahan* activities). Activities will be carried out together in mutual cooperation (*Pawongan* activities).

The second concept, known as space (*desa*), time (*kala*), and circumstance (*patra*), suggests that individuals are active agents who continuously adapt to the environmental conditions influencing their lives. This Desa Kala Patra framework provides a lens through which to understand the variations in *Subak* irrigation management rules applied in different Balinese communities' locations. The third mapping concept is that modern management functions have been implemented in every *Subak* activity, from planning, organizing, actuating, and controlling [23]. So, in the end, it will map *Subak*'s knowledge in the category of artifacts and practices. According to the UNESCO Convention in 2021, intangible cultural heritage encompasses a wide range of practices, representations, expressions, knowledge, skills, instruments, objects, and artefacts that exist across diverse cultural contexts [22].

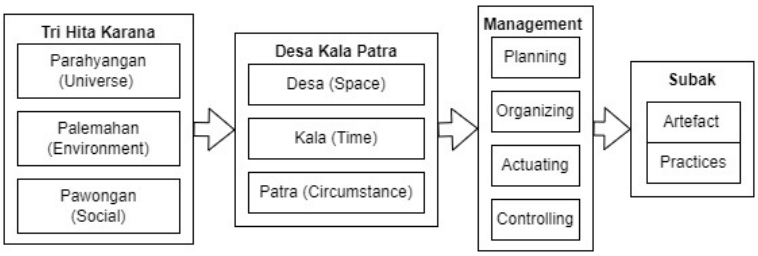


**Figure 2.** *Subak* ontology-based data Framework

Information representation operates on two distinct levels: syntax, which emphasizes the volume or structure of the information, and semantics, which focuses on the meaning of the information and its relationships with other concepts [31]. Ontology is an alternative to represent the knowledge domain, where this method helps in modelling semantic concepts and logical language.

Ontology modelling framework refers to CIDOC-CRM that allows information integration, mediation, and exchange of heterogeneous cultural heritage data and its correlation with digital libraries [32], [33], [34]. Knowledge will be modelled in the ontology concept. The concept of knowledge ontology has several main components, namely: Classes: explain concepts, general things from knowledge in a domain. A class has subclasses that are intended to express more specific concepts than the superclass. Properties are two-way relationships that connect classes with other classes to form knowledge/concept links. There are two types of ontology properties, namely object properties which connect objects with other objects, and data properties which connect objects with data type values (text, string or number). Object properties define the relationship between classes, where Subclass is an inheritance relationship. Data Properties is properties of data that represent attribute of the class. Instances/particular things/objects are individuals/members, which are actual objects of a class containing facts/information from a concept/knowledge. Constrains are rules for these things. Relationship is the concept of relationships between these things. Functions are processes that involve these things. Protégé is used to help visual depiction of knowledge concepts. This stage produces class hierarchy and an ontology graph.

Ontology development can be classified into two categories: (i) creation from scratch [35] and (ii) reuse and integration with existing ontologies based on the specific knowledge representation needs [36]. In this study, the ontology was developed from scratch to provide flexibility for knowledge expansion, as the process of collecting *Subak* knowledge is conducted incrementally.

## *Implementation*

The KMS *Subak* ontology-based knowledge base publication technology will be based on the semantic web, translating ontology into OWL, XML, RDF, and SPARQL as a query language. RDF (Resource Description Framework) is a standard framework for representing data through web-based graphics. RDF describes resources and the relationships between those resources in the form of subjects, predicates, and objects, known as triples. OWL(Web Ontology Language) creates ontologies on the semantic web. OWL used to define concepts, properties, and relationships between these concepts in more detail and formally. SPARQL Query Language is utilized to access and manage data structured in RDF (Resource Description Framework) format. SPARQL allows users to extract specific information from RDF datasets using syntax similar to SQL.

## *Evaluation*

Ontology evaluation involves external validation consisting of Competency Questions and Expert confirmation. Meanwhile, internal consistency using Ontology Metrics, which is accompanied by a graph ontology application, in this case, Protégé. Considering knowledge continues to develop, knowledge adequacy is addressed by enriching knowledge in a sustainable and structured manner. Ontology Metrics OntoQA [27][37] used in measuring ontology consistency include Schema Metrics (1)(2)(3), Knowledge base Metrics (4)(5), and Graph Metrics (6)(7)(8)(9)(10)(11). Each metric is calculated based on Equation 1-11.

*Schema Metrics* [27]

1. Attribute Richness (AR)

$$\mathrm{AR} = \frac{|\mathrm{att}|}{|\mathrm{C}|} \tag{1}$$

Where: |att| is the total number of attributes, and |C| is the total number of classes and subclass in the ontology.

2. Inheritance Richness (IR)

$$\mathrm{IR} = \frac{|\mathrm{H}|}{|\mathrm{C}|} \tag{2}$$

where |H| is the number of subclass relations, and |C| is the total number of classes in the ontology.

3. Relationship Richness (RR)

$$\mathrm{RR} = \frac{|\mathrm{P}|}{|\mathrm{H}| + |\mathrm{P}|} \tag{3}$$

where |P| is the total number of non-inheritance relations (object properties), and |H| is the total number of inheritance relations(subclasses).

*Knowledge base Metrics* [37]

1. Average Population (AP)

$$\mathrm{AP} = \frac{|\mathrm{I}|}{|\mathrm{C}|} \tag{4}$$

where |I| is the total number of instances of the knowledge base, and |C| is the total number of classes

2. Class Richness (CR)

$$\mathrm{CR} = \frac{|\mathrm{C}'|}{|\mathrm{C}|} \tag{5}$$

where |C'| is the number of classes in the knowledge base, and |C| is the total number of classes

*Graph Metrics* [37]

1. Absolute Root Cardinality (ARC)

$$ARC = n_{ROO \subseteq g} \quad (6)$$

where $n_{ROO \subseteq g}$ represents the number of elements in the set of root nodes ROO in the directed graph g.

2. Absolute Leaf Cardinality (AC)

$$AC = n_{LEA \subseteq g} \quad (7)$$

where $n_{LEA \subseteq g}$ represents the number of elements in the set of leaf nodes LEA in the directed graph g.

3. Average Depth (AD)

$$AD = \frac{1}{n_{p \subseteq g}} \sum_{j}^{P} N_{j \in P} \quad (8)$$

where $N_{j \in P}$ represents the number of elements on the path j that belong to the set of paths p in the directed graph g.

4. Maximum Depth (MD)

$$MD = N_{j \in P} \forall i \exists j (N_{j \in P} \geq N_{i \in P}) \quad (9)$$

Where $N_{j \in P}$ is the number of elements on the path j, and $N_{i \in P}$ is the number of elements on the path i, which belong to the set of paths P in the directed graph g.

5. Average Breadth (AB)

$$AB = \frac{1}{n_{L \subseteq g}} \sum_{j}^{L} N_{j \in L} \quad (10)$$

where L represents the set of levels in the directed graph g; $n_{L \subseteq g}$ is the number of elements in L, and $N_{j \in L}$is the number of elements on the level j.

6. Maximum Breadth (MB)

$$MB = N_{j \in L} \forall i \exists j (N_{j \in L} \geq N_{i \in L}) \quad (11)$$

where $N_{j \in L}$ and $N_{i \in L}$ are the number of elements on the level j and i respectively that belong to the set of levels L in the directed graph g.

## Conclusion

We have discussed the specifics of our research into one area of cultural preservation, the traditional Subak irrigation system in Bali. Our contributions include creating an ontology to capture *Subak*'s largely implicit and fragmented knowledge and externalizing it, which has not been discussed in previous research. This research provides innovation in the documentation and digitization of Subak irrigation and cultural systems through an ontology-based approach. The framework produced in this study integrates the Balinese philosophical basis of Tri Hita Karana, Desa Kala Patra, and POAC management modern, which are founded on Balinese cultural principles, are used to collect, classify, and organize cultural artifacts and apply knowledge. The methodology includes the Externalization of Knowledge, Modeling and Development, Implementation and evaluation stages. Model verification and validation are carried out through consultation with local experts, domain experts, the Subak community, and academics. This approach ensures that the ontology developed is valid, comprehensive, and relevant. This iterative and participatory process allows the ontology model to be adjusted to suit user needs and research developments. The resulting ontology will be used in order to facilitate knowledge sharing and the development of a prototype online digital portal for *Subak* Bali. We are now developing an ontology within the suggested framework and integrating it into the online digital portal system. For implementation, community-based crowdsourcing will be required to provide more detail in order to improve and update the knowledge provided. The *Subak* ontology will be expanded using user input, and the functionality of the digital portal will be improved. This ontology model provides an extensible basis for documenting other cultures, making it a long-term reference for research into local Indonesian culture and the application of technology for sustainable cultural preservation. The ontology development and modeling framework can be a

reference in developing new ontologies from scratch on other unstructured cultural heritage data, especially in the domain of agriculture and social organizations which are often found in agricultural countries.

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# Designing an e-report system as a digital portfolio in early childhood education in Surabaya using the waterfall method

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**Abstract:** This study focuses on the design and implementation of an E-Report system as a digital portfolio for Early Childhood Education in Genteng District, Surabaya. The current manual process using Excel and Canva for generating learning reports limits efficiency and accuracy in tracking children's developmental progress. To address this, a web-based E-Report system was developed using the Waterfall method to streamline reporting processes, allowing educators to manage children's data digitally while providing parents accessible, real-time progress reports. Development stages included requirement analysis, system design, and implementation, leveraging modern web technologies for optimal performance. User satisfaction assessments reveal high satisfaction levels, particularly in the system's format (average score of 3.80) and content (average score of 3.65), indicating a strong alignment with user needs. The implementation of the E-Report system is expected to elevate Early Childhood Education services in Genteng District by delivering a more efficient, accurate, and collaborative reporting tool.

**Keywords:** E-report system, early childhood education, web-based application, waterfall method, End-User Computing Satisfaction (EUCS).

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## Introduction

Early Childhood Education plays a critical role in laying the foundation for children's overall development. The importance of Early Childhood Education is emphasized in Indonesia's National Education System Law No. 20 of 2003, which recognizes the significance of supporting children's holistic growth, both physically and mentally [1]. As part of this mandate, the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek) introduced policies to strengthen the transition from Early Childhood Education to elementary school. A key element of this policy is the use of the Early Childhood Education Learning Outcome Report, which serves as a vital tool for evaluating a child's progress and involving parents in their education [2]. This report not only strengthens the connection between schools and families but also helps parents provide more targeted support based on their child's needs [3].

Despite its importance, many Early Childhood Education institutions in Genteng District, Surabaya, continue to rely on manual processes using Excel and Canva to create learning reports. While these digital tools provide basic functionality, they fall short in terms of efficiency and accuracy. Manual processes are time-consuming and prone to errors, such as data duplication and inconsistent formatting of student profiles [4]. This has highlighted the need for a more efficient and accurate approach to monitoring children's development. Information technology plays a pivotal role in improving the management and reporting of data in educational institutions, especially in Early Childhood Education, where monitoring growth and progress is crucial [5].

To address these challenges, this study proposes the development of a web-based E-Report system as a digital portfolio for Early Childhood Education in Genteng District. The system aims to streamline the process of data management, enhance the accuracy of reports, and pro-

vide online access for parents and educators [6]. By utilizing centralized data storage and advanced analysis features, the system will offer a comprehensive digital portfolio for children's development [7].

The development process will follow the Waterfall methodology, ensuring a structured approach from requirement analysis to system implementation [8]. The Waterfall Method is well-documented for its structured approach to software development. Afandi [9] discuss how this methodology, involving sequential phases such as requirements analysis, system design, implementation, testing, and maintenance, is effective for projects with well-defined requirements. Applying the Waterfall Method to the design of an e-report system ensures a systematic and organized development process, making it suitable for the project in Surabaya.

This solution is expected to not only improve the efficiency of progress monitoring in Early Childhood Education but also strengthen the partnership between educators and parents, ultimately enhancing the quality of Early Childhood Education services in Genteng District.

## Methodology

This study focuses on designing an E-Report system for Early Childhood Education in Surabaya using the Waterfall method. The research aims to address the limitations faced by educational institutions in utilizing Excel and Canva for reporting purposes. The methodology for system development is illustrated in Figure 1.


**Figure 1.** Methodology

The methodology begins with identifying the problems encountered by Early Childhood Education institutions in Surabaya. Field observations and interviews with key stakeholders, including educators and administrators, were conducted to gather insights into the current challenges and needs related to reporting. This initial phase is crucial for understanding the specific requirements and pain points of the users [10].

In the design phase, the identified requirements are translated into a structured system using the Waterfall model. This model is chosen for its sequential and systematic approach, which helps in developing a clear and organized E-Report system. Key features of the system include user logins for different roles (teachers, administrators, parents, and students), data entry for student information, and digital report management. The goal is to create a system that simplifies report generation and enhances communication between educators and parents.

The development process involves creating detailed design specifications, followed by the implementation of the system. Once the system is developed, it undergoes black-box testing to ensure that all functionalities, such as data management and report generation, work as intended.

By employing the Waterfall method, this study ensures that each phase of the system development is completed before moving on to the next, thereby providing a clear and structured approach to designing and implementing the E-Report system.

### *Identification Of Problem*

In the problem identification phase, this research focuses on the challenges faced by Early Childhood Education institutions in Genteng District regarding their use of Excel and Canva for reporting student progress. This process begins with a field study that involves direct observation and interviews with district leaders and administrators to understand the challenges and needs for digital transformation. Following this, a literature review is conducted to establish a strong theoretical foundation by examining relevant literature and previous research [10]. This helps in

identifying gaps in knowledge and opportunities for innovation, which are essential for developing an effective E-report system that addresses the identified needs and provides relevant solutions.

## *System Design And Development*

In the system design and development phase, the focus is on creating a comprehensive framework for the E-report system. This stage involves translating the identified needs and requirements into a functional design. Key elements of this phase include the development of use case diagrams, activity diagrams, and system wireframes [11].

Use case diagrams are created to outline the interactions between users and the system, detailing the various scenarios in which the system will be utilized. Activity diagrams are used to map out the flow of processes and actions within the system, providing a clear visualization of the steps involved in each process. System wireframes are developed to create a visual blueprint of the user interface, illustrating the layout and elements of the system to ensure that it meets user requirements and is easy to navigate. This comprehensive design approach ensures that all aspects of the system are well-defined and aligned with the project's goals before moving on to the implementation phase. Usecase diagram of the application shown in Figure 2.

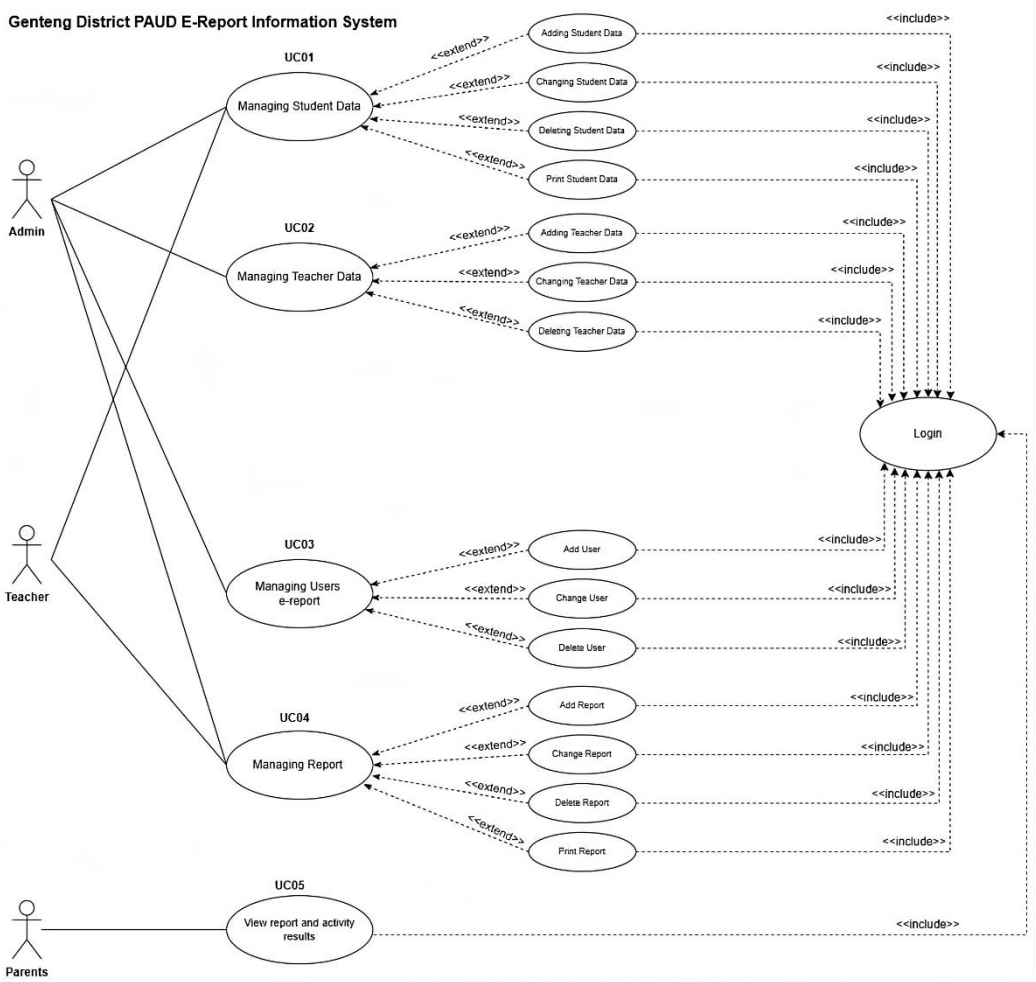


**Figure 2.** Use case diagram of application

Based on the use case diagram shown in Figure 2, there are three actors: Admin, Teacher, and Parent. Each use case has a prerequisite that must be met, indicated by the include arrow, which is the Login process. Therefore, actors must log in to access any use case. The following is a summary of the use cases detailed in Table 1 below:

**Table 1.** Description of use case diagram

| Use Case | Description |
|---|---|
| UC01 Manage Student Data | Admin and Teacher can access functions to manage student data, including adding, updating, deleting, and printing student records, ensuring that the data remains current for school reporting purposes. |
| UC02 Manage Teacher Data | Admin can access functions to manage teacher data, including adding, updating, and deleting records, and assigning student groups to teachers to ensure effective education and monitoring. |
| UC03 Manage E-Report Users | Admin can access functions to manage E-Report users, including adding, updating, and deleting users to maintain system security and access validity. |
| UC04 Manage Report Card Grades | Teacher can access functions to manage report card data, including adding, updating, deleting, and printing grades based on defined developmental aspects to continuously monitor student progress. |
| UC05 View Report Card and Activities | Parents can access functions to monitor report card results and student activities, providing them with insights into their child's educational development and school activities. |

All actors must log in to access these functions, ensuring that only authenticated users can manage and monitor the data.

In the activity diagram designed for this information system, there are six diagrams: managing student data, managing teacher data, managing activity information, managing e-report users, managing report card grades, and viewing report card results and activities.

An overview of the activity diagram for managing student data used in the e-report system can be seen in Figure 3. Figure 3 outlines the following process: First, the Admin or Teacher accesses the login page and enters their username and password. The system then verifies these credentials. If they are correct, the user is redirected to the dashboard page. From there, the Admin or Teacher can navigate to the student data management page, where they have the option to add, modify, or delete student data. After any action is performed, the system updates the data and displays the results.

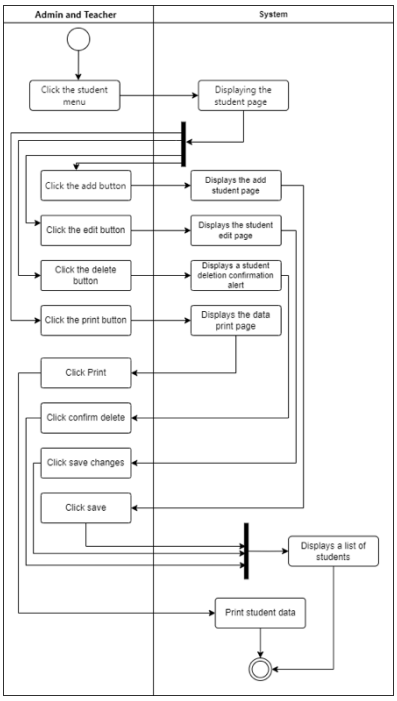


**Figure 3.** Student data management activity diagram

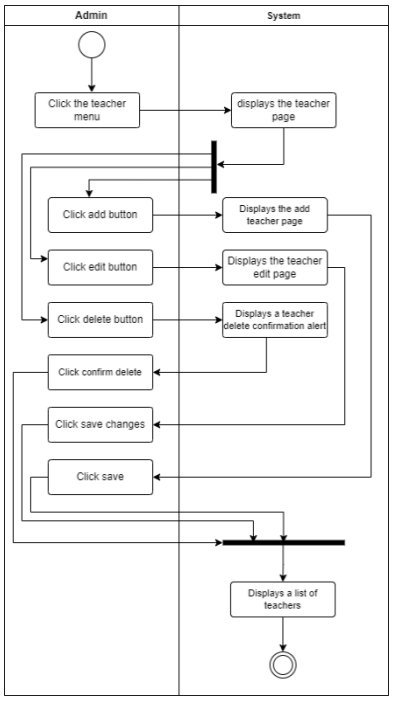


**Figure 4.** Teacher data management activity diagram

An overview of the activity diagram for managing teacher data used in the e-report system can be seen in Figure 4. Figure 4 illustrates the following process: The Admin begins by accessing the login page and entering their username and password. The system then verifies these credentials. If they are valid, the Admin is redirected to the dashboard page. From there, the Admin can navigate to the teacher data management page, where they have the option to add, modify, or delete teacher data. After any action is executed, the system updates the data and presents the results

An overview of the activity diagram for managing e-report users used in the e-report system can be seen in Figure 5. Figure 5 outlines the following process: The Admin starts by accessing the login page and entering their username and password. The system then verifies these credentials. If they are correct, the Admin is directed to the dashboard page. From there, the Admin can navigate to the e-report user management page, where they have the option to add, modify, or delete e-report users. After any action is performed, the system updates the data and displays the results.

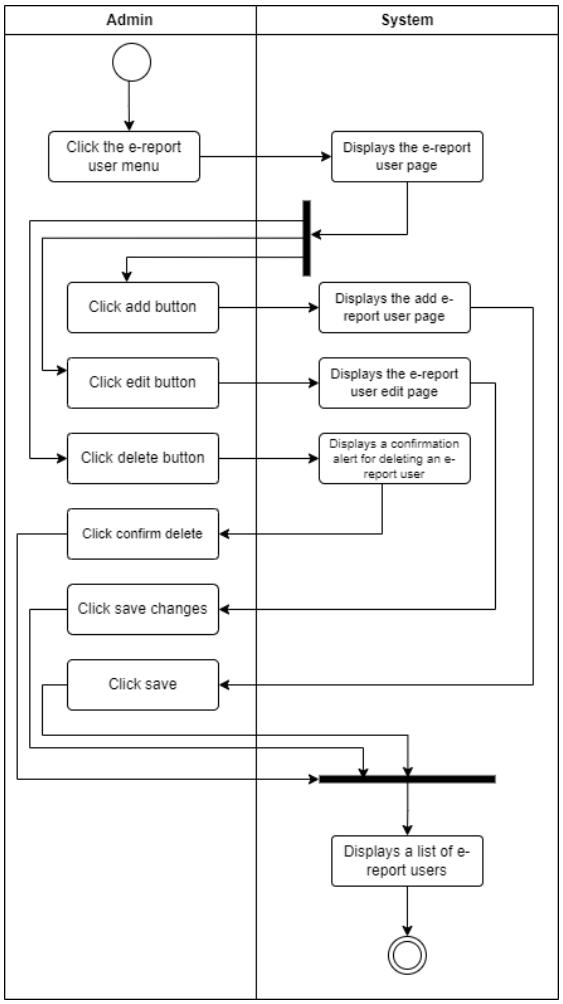


**Figure 5.** E-report user management activity diagram

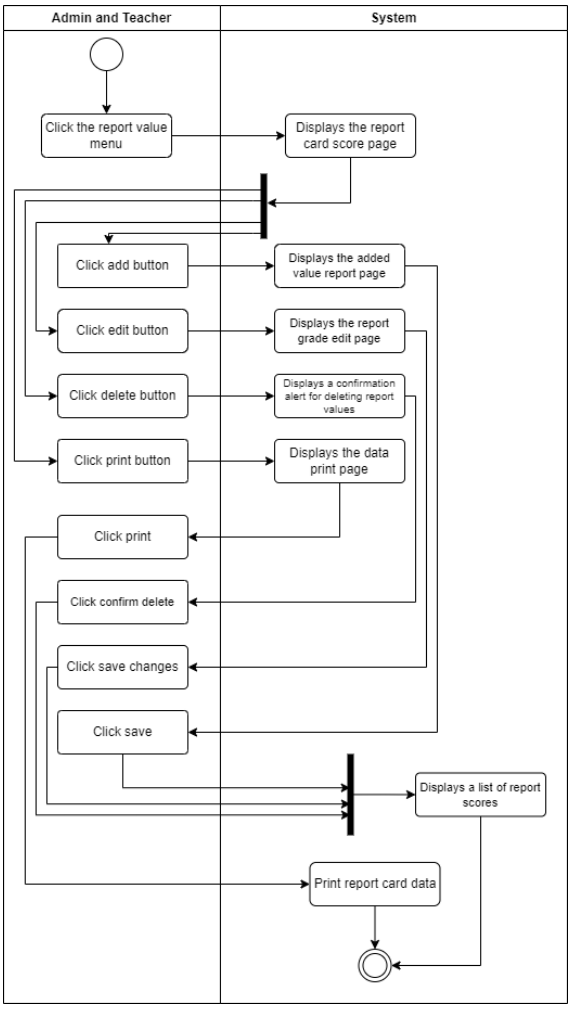


**Figure 6.** Report card grades management activity diagram

An overview of the activity diagram for managing report card grades used in the e-report system can be seen in Figure 6. Figure 6 describes the following process: The Teacher starts by opening the login page and entering their username and password. The system then verifies these credentials. If they are correct, the Teacher is redirected to the dashboard page. From there, the Teacher can access the report card grade management page, where they can add, modify, or delete student report card grades. Once an action is performed, the system updates the data and displays the results.

An overview of the activity diagram for viewing report card results and activities used in the e-report system can be seen in Figure 7. Figure 7 outlines the following process: The Student begins by opening the login page and entering their username and password. The system then verifies these credentials. If they are correct, the Student is directed to the dashboard page. From there, the Student can navigate to the page where they can view report card results and activity information.

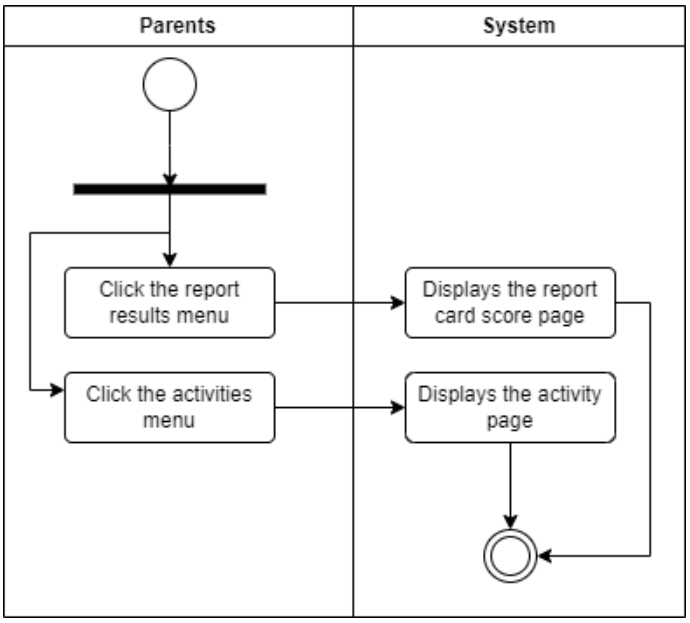


**Figure 7.** Activity diagram for viewing report card results and activities

The system wireframe is an abstract design for the website to be developed [12]. This design aims to identify which features will be implemented on the website and the layout that will be used during the development process [13]. The wireframe includes the core design elements of the website, such as the main dashboard view, the dropdown menu view on the main menu, the data input view, and the layout view of the e-report that will be generated as a PDF. These four wireframe designs encompass the entire website, as other menu displays are similar, differing only in data and naming conventions. This approach ensures that the website development process, when transitioning from a sketch to coding, can directly meet the required needs.

Figure 8 illustrates the wireframe for the main and dropdown menus. The main menu provides primary navigation options for users, including key sections of the application. The dropdown menu, accessible from the main menu, offers additional, context-specific choices. This design helps streamline user interactions by consolidating related options. Overall, the wireframe ensures a user-friendly layout and efficient navigation throughout the application.

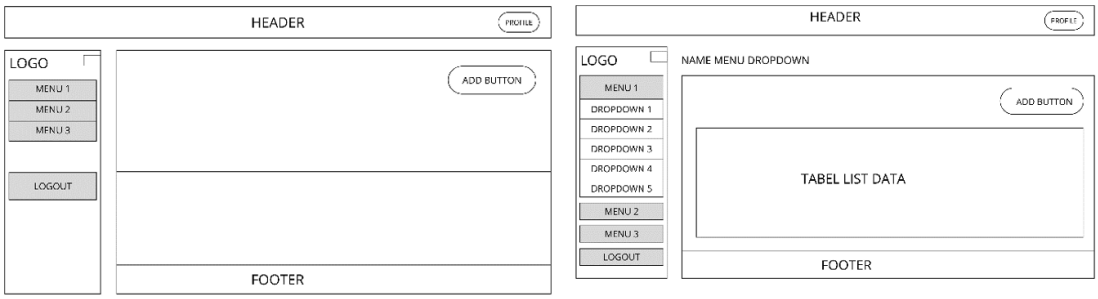


**Figure 8.** Main and dropdown menu wireframe

Figure 9 illustrates the wireframe for displaying a report as a PDF. It shows the layout and interface elements involved in generating and viewing the PDF report. The wireframe includes options for selecting print settings and previewing the document. This design aims to provide a clear, user-friendly method for accessing and managing PDF reports.

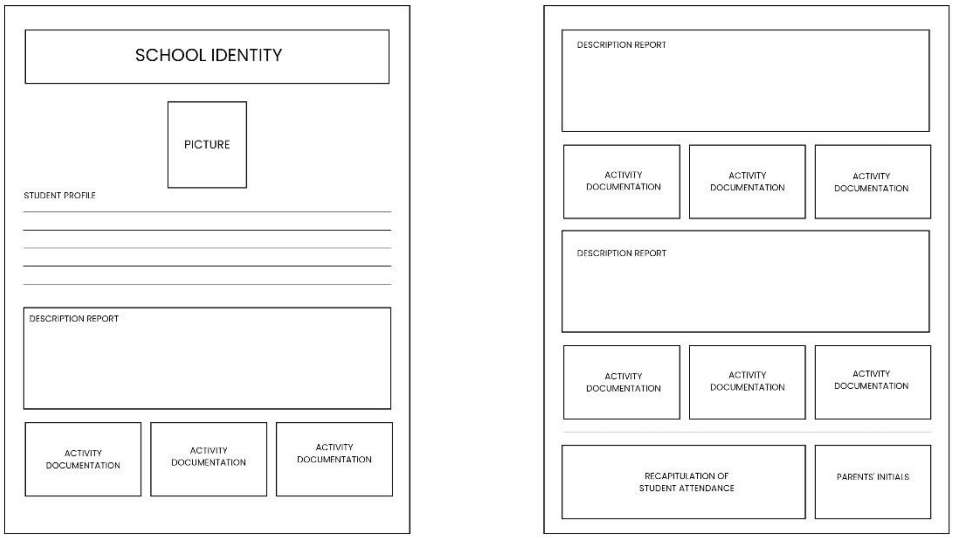


**Figure 9.** Print report as PDF wireframe

The next phase involves the implementation of the results from the problem identification and system design stages. Following this, the system undergoes testing using black-box testing methods to assess and adjust the features that will be evaluated. Black-box testing, focusing on the functionality of the system without peering into its internal structures, will help ensure that all components operate as intended and meet user requirements.

The aim of this comprehensive testing process is to validate that the system is robust, user-friendly, and aligns with the initial design specifications. By meticulously addressing any issues discovered during testing, we hope to deliver a fully functional and reliable system that effectively meets the needs and expectations of its users. This approach ensures that the final product will not only function correctly but also provide a seamless and satisfying user experience.

## Results and Discussions

### *System Implementation*

The following are displays of various menus that have been developed based on the problem identification findings from the methodology phase. Figure 10 depicts the wireframe for the login page. It features fields for entering a username and password, along with a button to submit the login credentials. The design includes options for password recovery and user registration, enhancing accessibility for new and existing users. Additionally, there is a visual indicator for input errors to guide users in correcting mistakes. The layout is streamlined to ensure a simple and intuitive login process. Overall, the wireframe aims to provide a clear and efficient entry point into the application.

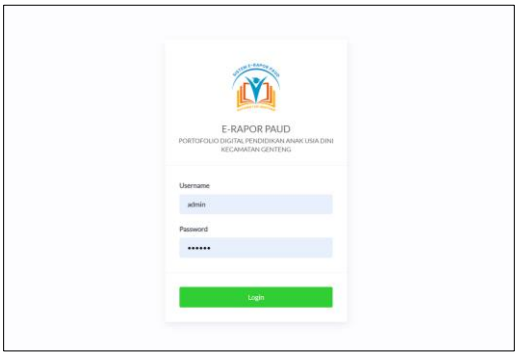


**Figure 10.** Login page

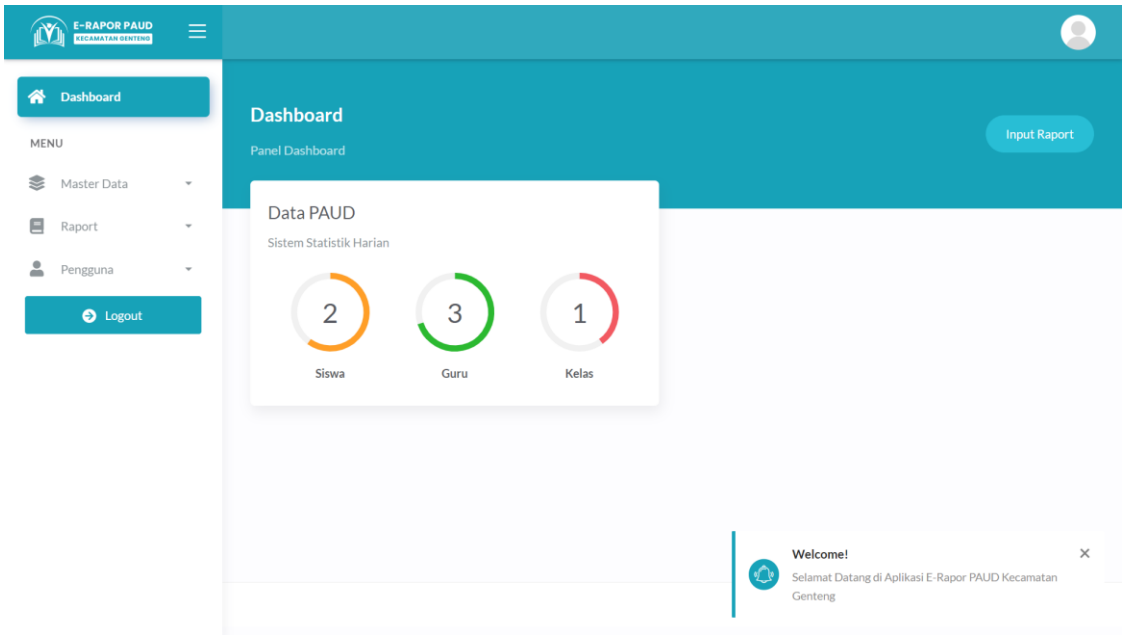


**Figure 11.** Main dashboard

Figure 11 represents the interface of an application or system called E-Report Early Childhood Education. This dashboard is designed to offer an overview of key metrics and performance indicators related to Early Childhood Education. It features widgets that display real-time data, allowing users to stay updated with the latest information. The layout of the dashboard is customizable, so users can adjust it according to their preferences, such as by adding, removing, or rearranging widgets. A navigation bar on the side provides easy access to various sections of the application, facilitating smooth transitions between different features or modules. Additionally, alerts and notifications are prominently displayed to ensure that important updates and critical information are not missed.

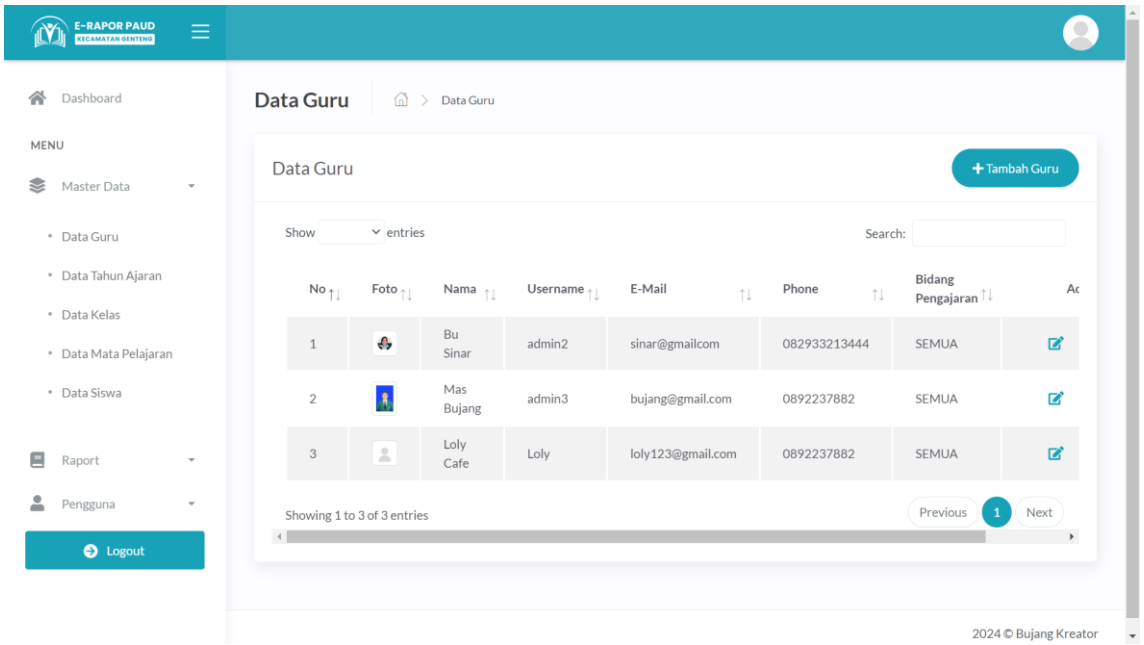


**Figure 12.** Main menu of teacher data

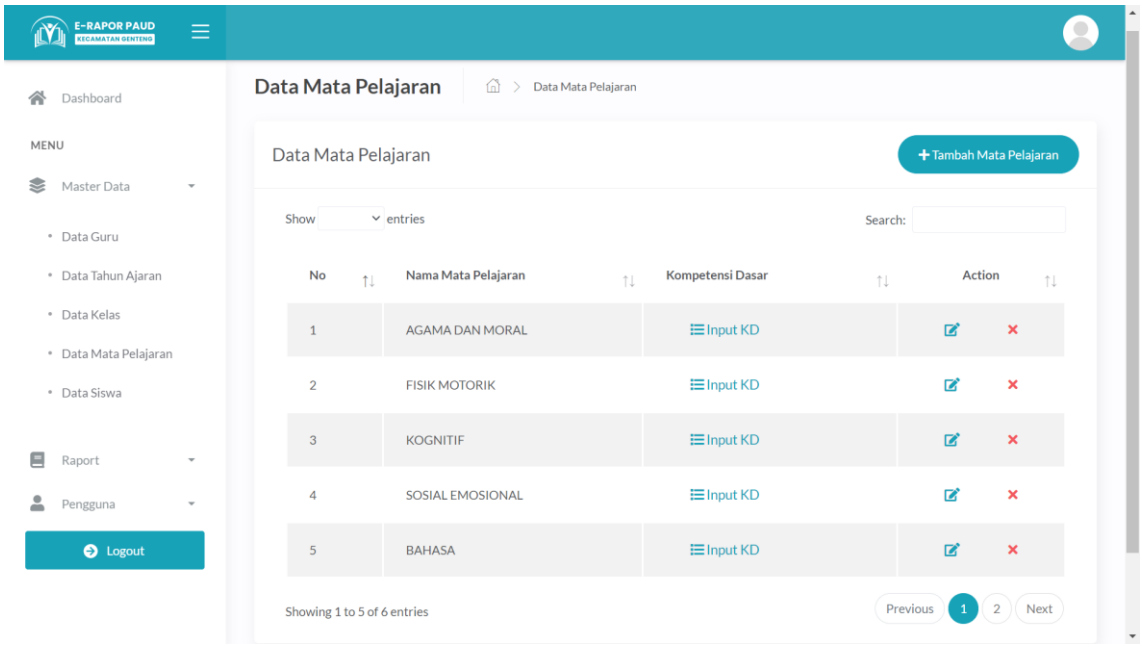


**Figure 13.** Main menu of subjects

Figure 13 displays the primary interface for accessing various educational subjects, including Religion and Morality, Physical Motor Skills, Cognitive Development, Socio-Emotional Skills, and Language. Each subject area is represented as a separate category on the menu, allowing users to navigate directly to the relevant section. The menu is designed to provide an organized overview of the different domains of early childhood education, ensuring that educators can easily find and manage content related to each subject. Users can click on each category to access detailed information, resources, and tools specific to that area. This structured layout helps streamline the process of curriculum planning and tracking student progress across multiple domains of development.

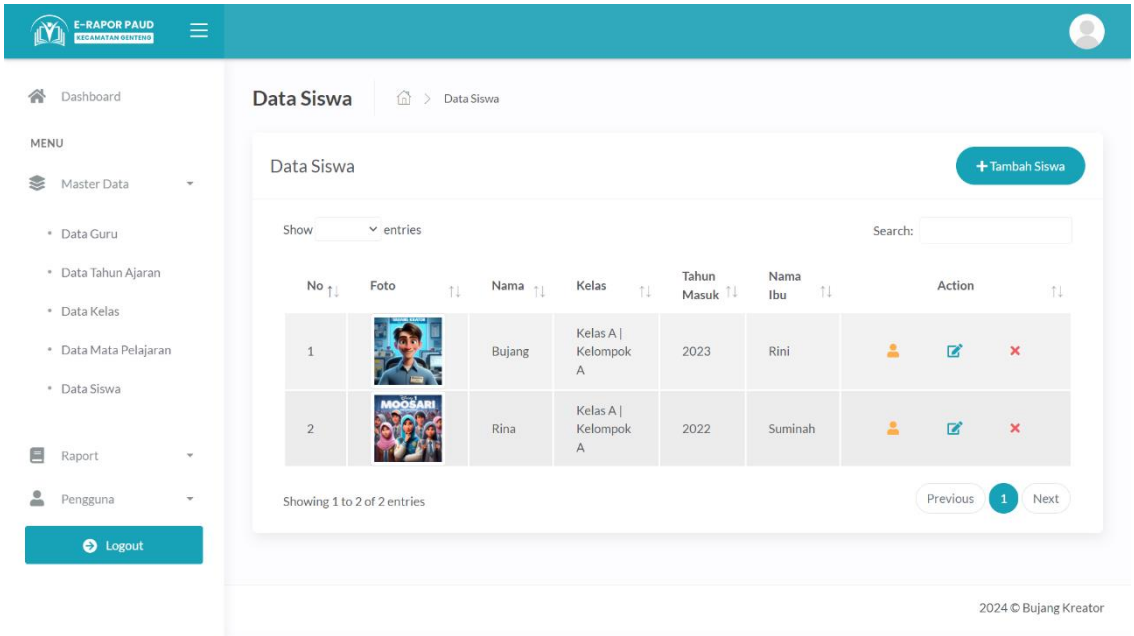


**Figure 14.** Main menu of student data

Figure 14 shows the main interface used for managing student data within the application. This menu provides direct access to various important information about each student, including personal data and enrollment year.

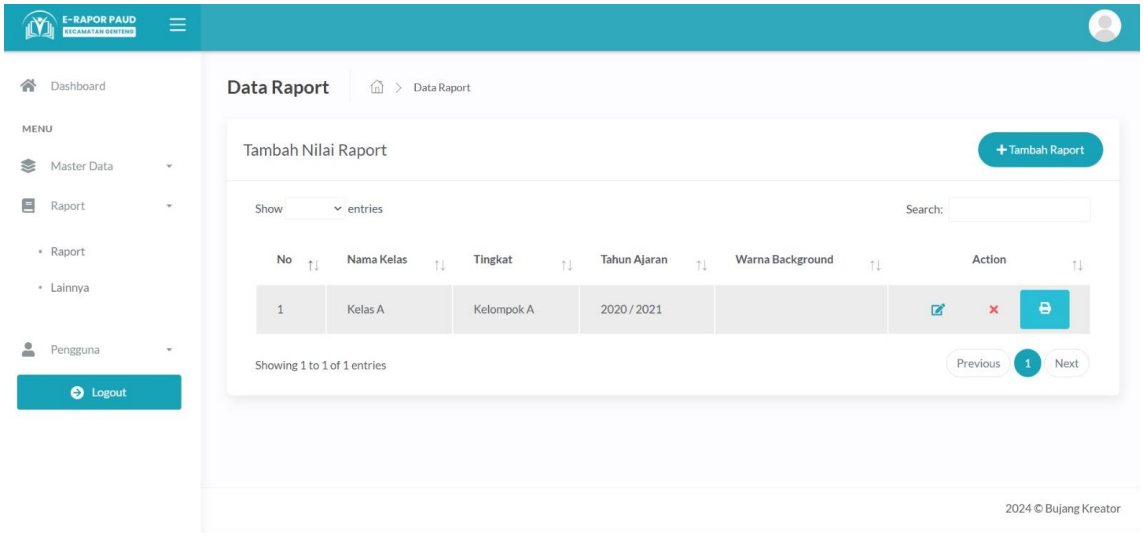


**Figure 15.** Report data menu

Figure 15 provides access to various reporting features, allowing users to generate and view detailed reports on student performance and academic progress. This menu includes options for creating reports that cover key areas such as Religion and Morality, Physical Motor Skills, Cognitive Development, Socio-Emotional Skills, and Language. Users can customize reports to focus on these specific domains, enabling a comprehensive analysis of each student's development across different areas. The interface allows for filtering and sorting data to refine the reports according to particular criteria or time periods. Additionally, reports can be exported in various formats, making it easier to share and utilize the information for educational planning and assessments.


**Figure 16.** Result of print data s-raport

Figure 16 provides access to various reporting features, allowing users to generate and view detailed reports on student performance and academic progress. This menu includes options for creating reports that cover key areas such as Religion and Morality, Physical Motor Skills, Cognitive Development, Socio-Emotional Skills, and Language. The results of printed data from E-Raport include comprehensive details along with photos of student activities, providing a visual

representation of their engagement and progress. Each report highlights specific aspects of the student's development in the mentioned areas, offering a well-rounded view of their performance. The inclusion of photos and detailed evaluations helps educators and parents gain a deeper understanding of the student's achievements and areas for improvement. The interface allows for easy customization and export of these reports, ensuring that all relevant information is effectively communicated and utilized.

## *Blackbox Testing*

Following the implementation phase, the next step is to test the system to confirm that it meets the requirements of its users [15] . In this study, Black-box testing is employed to evaluate the e-report system. This testing method focuses on assessing the system's functionality without examining its internal workings. The goal is to identify any residual errors and ensure that the system functions as intended and meets the specific needs outlined during the design phase. The results of black-box testing can be shown in Table 2, Table 3, Table 4, Table 5, and Table 6.

**Table 2.** Black-box testing for login and dropdown menu

| Type of Request | Type of User | Input | Expected Output | The Output Produced | Concluded |
|---|---|---|---|---|---|
| Login | Admin/Teacher | Email and Password | Dashboard view | Dashboard view | Succeeded |
| Dropdown Menu | Admin/Teacher | Click on dropdown | Dropdown menu opens | Dropdown menu opens | Succeeded |

**Table 3.** Black-box testing for input data and manage student data

| Type of Request | Type of User | Input | Expected Output | The Output Produced | Concluded |
|---|---|---|---|---|---|
| Input Data | Admin | Teacher details | Data input form displayed, data saved | Data input form displayed, data saved | Succeeded |
| Manage Student Data | Admin/Teacher | Add/Update/Delete records | Student records updated or added | Student records updated or added | Succeeded |

**Table 4.** Black-box testing for manage teacher data and manage e-report users

| Type of Request | Type of User | Input | Expected Output | The Output Produced | Concluded |
|---|---|---|---|---|---|
| Manage Teacher Data | Admin | Add/Update/Delete records | Teacher records updated or added | Teacher records updated or added | Succeeded |
| Manage E-Report Users | Admin | Add/Update/Delete users | E-Report users updated or added | E-Report users updated or added | Succeeded |

**Table 5.** Black-box testing for manage report card grades and view report card and activities

| Type of Request | Type of User | Input | Expected Output | The Output Produced | Concluded |
|---|---|---|---|---|---|
| Manage Report | Teacher | Add/Update/Delete grades | Grades updated or added | Grades updated or added | Succeeded |

| | | | | | |
|---|---|---|---|---|---|
| Card Grades | | | | | |
| View Report Card and Activities | Parent | View report card and activities | Report card and activity information displayed | Report card and activity information displayed | Succeeded |

**Table 6.** Black-box testing for logout

| Type of Request | Type of User | Input | Expected Output | The Output Produced | Concluded |
|---|---|---|---|---|---|
| Logout | Admin/Teacher/Parent | Click Logout | Redirect to login page | Redirect to login page | Succeeded |

## *End User Computing Satisfaction*

End user computing satisfaction in the context of designing an e-report system as a digital portfolio for early childhood education in Surabaya is crucial to ensure the system's effectiveness. By employing the Waterfall method, each development phase from requirements analysis to implementation can be tailored to meet the expectations of users, such as teachers and parents, regarding ease of access and clarity of information. An intuitive interface and features that align with the specific needs of early childhood education will significantly enhance user satisfaction. Additionally, gathering feedback from users during the testing phase can help identify and resolve issues before the final launch, creating a system that is not only functional but also enjoyable to use. Ultimately, this approach aims to improve the management of data and documentation of children's development effectively.

**Table 7.** List of questions

| Category | ID | Question |
|---|---|---|
| Content | C01 | I understand the purpose of this system |
| | C02 | I feel that this system has helped me in conducting student assessments |
| Format | F01 | I feel that the design of this system is very modern and elegant. |
| | F02 | I feel that the layout of this system is well-organized |
| Timeline | T01 | I often encounter difficulties in using and accessing this system |
| | T02 | This system is difficult to access under certain circumstances |
| Ease of Use | E01 | I need help using this system |
| | E02 | I feel that this system is complicated to use. |
| Accuracy | A01 | I feel that there are many inconsistencies in this system |
| | A02 | I find this system confusing |

To quantitatively measure user satisfaction with the e-report system, a structured questionnaire based on the End User Computing Satisfaction (EUCS) framework was developed. This questionnaire evaluates five key variables: Content, Format, Timeliness, Ease of Use, and Accuracy. Each variable comprises specific questions aimed at assessing different aspects of user interaction and experience with the system. The responses to these questions were gathered using a Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), allowing for a detailed analysis of user perceptions and satisfaction. The results from this survey provide valuable insights into areas where the system performs well and where improvements are needed to enhance overall user satisfaction.

**Table 8.** Likert scale

| Perceptions | Score |
|---|---|
| Strongly Disagree | 1 |
| Disagree | 2 |
| Neutral | 3 |
| Agree | 4 |
| Strongly Agree | 5 |

Table 9 represents the satisfaction levels from the Likert scale:

**Tabel 9.** Satisfaction levels

| Range | Perception Rating | Satisfaction Rating |
|---|---|---|
| 1 – 1.79 | Strongly Disagree | Very Dissatisfied |
| 1.8 – 2.59 | Disagree | Dissatisfied |
| 2.6 – 3.39 | Neutral | Moderately Satisfied |
| 3.4 – 4.19 | Agree | Satisfied |
| 4.2 – 5 | Strongly Agree | Very Satisfied |

Table 9 can be used to assess satisfaction for each variable. It also serves as a reference for calculating the average of the responses collected from the questionnaire.

**Tabel 10.** Questionnaire results for each category

| Variable | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| C01 | 0 | 0 | 17 | 5 | 8 |
| C02 | 0 | 0 | 17 | 8 | 5 |
| F01 | 0 | 0 | 15 | 5 | 10 |
| F02 | 0 | 0 | 12 | 13 | 5 |
| T01 | 0 | 0 | 20 | 5 | 5 |
| T02 | 0 | 0 | 25 | 0 | 5 |
| E01 | 0 | 8 | 17 | 0 | 5 |
| E02 | 0 | 3 | 17 | 5 | 5 |
| A01 | 0 | 10 | 15 | 0 | 5 |
| A02 | 0 | 5 | 20 | 0 | 5 |

The results presented in Table 10 highlight the average scores and corresponding satisfaction categories for various variables evaluated in this study. Each variable—Content, Format, Timeliness, Ease of Use, and Accuracy—was assessed to gauge user satisfaction with the e-report system designed for early childhood education in Surabaya.

The average scores were derived from a user satisfaction survey conducted among the system's end-users, including educators and parents in the Early Childhood Education community. A total of 30 respondents participated in the survey, which was designed based on the EUCS (End-User Computing Satisfaction) model. The questionnaire consisted of variables such as Format, Content, Ease of Use, Accuracy, and Timeliness.

Each variable was rated on a Likert scale ranging from 1 (Strongly Dissatisfied) to 5 (Strongly Satisfied). The "Format" variable, with an average score of 3.800, indicated a "Highly Satisfied" perception among users, reflecting their approval of the system's layout and design. Conversely, the "Accuracy" variable received an average score of 3.083, categorized as "Neutral or Moderately Satisfied," highlighting potential concerns with the reliability of data or system outputs.

These scores were calculated by averaging the responses for each variable across all respondents. The results provide insights into user experiences and suggest that while the system excels in formatting, improvements are needed in ensuring the accuracy of information.

**Tabel 11.** Average of each variable

| Variable | Average Score | Category |
|---|---|---|
| Content | 3.650 | Satisfied |
| Format | 3.800 | Highly Satisfied |
| Timeliness | 3.417 | Satisfied |
| Ease of Use | 3.233 | Moderately Satisfied |
| Accuracy | 3.083 | Neutral or Moderately Satisfied |

## Conclusion

The implementation of the E-Report system represents a transformative step in addressing the challenges faced by Early Childhood Education institutions in Genteng District, Surabaya, which previously relied on manual reporting methods using Excel and Canva. The system has garnered significant positive feedback, particularly in its design and information quality. The format dimension, with an average satisfaction score of 3.80, highlights the system's success in delivering an intuitive and visually appealing layout that meets user expectations. Similarly, the content dimension scored 3.65, reflecting the system's capability to provide accurate, relevant, and well-structured information that enhances the reporting process.

Beyond these strengths, the E-Report system has also proven to be an effective tool in enhancing data accessibility and fostering stronger engagement between parents and educators. By enabling real-time access to detailed student progress reports, the system bridges the gap between home and school, supporting a more collaborative approach to monitoring and encouraging children's development. This functionality not only simplifies communication but also empowers parents to take a more active role in their child's education, aligning with the broader goals of Early Childhood Education.

However, despite these notable achievements, the analysis revealed areas that require further refinement. The ease of use dimension, with an average score of 3.23, indicates that while the system is functional, some users encountered challenges in navigating the interface. This suggests a need for enhancing the system's intuitiveness to ensure it is accessible to a broader range of users with varying levels of digital literacy. Similarly, the accuracy dimension, which scored 3.08, points to concerns about the reliability of data presented by the system. These findings underscore the importance of improving backend data validation processes and minimizing discrepancies to strengthen user trust in the system's outputs.

Timeliness also emerged as a factor with room for improvement. Although the system's responsiveness was generally satisfactory, achieving an average score of 3.42, further optimization could enhance its performance, particularly under conditions of high usage. Ensuring faster load times and seamless access across devices will not only improve user satisfaction but also solidify the system's reliability as a daily operational tool.

One of the most tangible benefits of the E-Report system lies in its potential to deliver significant cost efficiencies. By transitioning from traditional paper-based reporting methods to a fully digital platform, educational institutions can reduce expenses related to paper and printing. This shift not only aligns with sustainable practices but also provides long-term financial benefits, allowing resources to be redirected toward other educational priorities.

In conclusion, the E-Report system has demonstrated its capacity to address key reporting challenges in Early Childhood Education by providing a modern, efficient, and user-friendly solution. While the system has successfully delivered high satisfaction in areas such as format and content, it also offers valuable insights into areas that require further refinement, including ease of use, accuracy, and timeliness. These findings serve as a roadmap for future enhancements, ensuring that the system continues to evolve in response to user needs. Ultimately, the adoption of the E-Report system marks a significant milestone in modernizing educational practices, fostering better collaboration, and enhancing the overall quality of Early Childhood Education services in the Genteng District.

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