EVELUNE: A PERIOD AND POLYCYSTIC OVARY SYNDROME MANAGEMENT (PCOS) MOBILE APPLICATION USING K-MEANS CLUSTERING AND RULE-BASED PHASE PREDICTION

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ABSTRACT

Menstrual health plays a critical role in an individual's overall well-being, influencing physical, emotional, and reproductive health. Tracking menstrual cycles provides valuable insights into hormonal patterns, allowing for early detection of disorders such as hormonal imbalances. However, most period tracking applications are designed for users with regular cycles, often resulting in inaccurate predictions for individuals with irregular menstruation or Polycystic Ovary Syndrome (PCOS). This study proposes the development of Evelune, a menstrual and PCOS management mobile application that integrates K-Means Clustering and a rule-based prediction system to improve menstrual phase prediction and health awareness. The K-Means algorithm organizes user input into groups based on similarities in symptom patterns, which are then analyzed through a rule-based system that predicts menstrual phases and provides personalized health insights. Evelune further implements data privacy features such as AES-256 encryption, Firebase Authentication, HTTPS communication, and Multi-Factor Authentication (MFA) to ensure user data protection. The system is evaluated using ISO/IEC 25010:2023 quality standards, emphasizing functional suitability, usability, reliability, and security. Evelune aims to empower Filipino users, particularly those managing PCOS, by promoting reproductive health literacy, accurate symptom tracking, and privacy-conscious self-care practices.

KEYWORDS

Menstrual Health, Polycystic Ovary Syndrome (PCOS), K-Means Clustering, Rule-Based System, Mobile Health Application, Data Application, Data Privacy, Reproductive Health Literacy

1. INTRODUCTION

This section provides an overview of the research problem, its motivation, and the rationale for developing the proposed system. It discusses the gaps in existing menstrual tracking applications, the objectives and significance of the study, and how this research contributes to addressing PCOS-related challenges through adaptive technology and privacy-aware design.

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1.1. Background of the Study

Menstrual tracking applications have gained popularity for their convenience in monitoring menstrual health, but many are inadequate for users with irregular cycles caused by conditions like PCOS. PCOS affects approximately 4.5 million women in the Philippines and is characterized by hormonal imbalances that cause irregular periods, acne, and weight changes. Conventional apps rely on simple rule-based calculations and fail to account for the irregular patterns associated with PCOS, leading to user dissatisfaction and misinformation.

1.2. Problem Statement

Existing menstrual tracking applications lack the ability to adapt to irregular cycle patterns and fail to address the needs of users with PCOS. There is a need for a secure, personalized, and intelligent menstrual tracking application capable of accurate predictions, privacy compliance, and educational support for PCOS management.

1.3. Objectives

The general objective is to develop Evelune, a mobile application that integrates K-Means Clustering and rule-based logic for adaptive menstrual tracking and PCOS management. The specific objectives include:

1. Designing a menstrual tracking system that integrates K-Means clustering and rule-based prediction.
2. Implementing security measures such as AES-256 encryption, Firebase Authentication, HTTPS, and MFA.
3. Providing localized educational content and a moderated community forum to enhance menstrual health literacy.

1.4. Significance of the Study

Evelune addresses a crucial gap in femtech applications by providing adaptive menstrual tracking for both regular and PCOS-affected users. It supports self-awareness, non-clinical management, and privacy protection. The study benefits users, educators, and researchers by promoting menstrual health literacy, empowering women to understand bodily patterns, and contributing to the growing field of AI-assisted digital health applications.

1.5. Review of Related Works

Existing studies reveal that current menstrual apps lack inclusivity for PCOS users and often fail to provide accurate predictions for irregular cycles. Research by Kukreja (2025) and Broad (2022) emphasizes the need for user-centered designs and algorithmic transparency. Other studies (Rodriguez, 2020; Arabkermani, 2025) demonstrate that AI integration can improve personalization in health apps. However, privacy concerns remain a critical issue, as highlighted by Garamvolgyi (2022) and the Foundation for Media Alternatives (2023), underscoring the importance of strong data protection in reproductive health tools.

1.6. Contributions of the Study

This study contributes to the development of a privacy-conscious menstrual tracking system with:

- Integration of machine learning (K-Means Clustering) for adaptive tracking.
- A rule-based phase prediction system tailored to irregular cycles.
- Privacy and data protection measures compliant with Philippine data laws.
- Culturally relevant health education and community support features.

1.7. Paper Organization

Section II presents the methodology and system design. Section III discusses the results and findings. Section IV concludes with the implications, limitations, and recommendations for future work.

2. Methodology And System Design

This section details the technical design, development process, and evaluation methods used to build Evelune. It explains the research design, system architecture, algorithims implemented, security framework, and evaluation criteria aligned with software quality standards.

2.1. Research Design

The study employed a quantitative research design, using statistical data collection and analysis to evaluate system usability, accuracy, and performance. Users provided structured feedback through Likert-scale evaluations based on ISO/IEC 25010:2023 standards.

2.2. System Development Methodology

The Agile Software Development Life Cycle was adopted, consisting of iterative phases: Planning, Requirement Analysis, Designing, Building, Testing, and Deployment. This approach allowed rapid feedback, flexibility, and user-focused refinement.

2.3. System Architecture

Evelune consists of a mobile front-end, a secure backend, and a Firestore database. The mobile app enables users to log symptoms, access educational content, and interact with the forum. The backend handles clustering analysis, rule-based prediction, and data encryption. Admin functions include moderation and report management.

Figure 1. User Interface Design of the Application

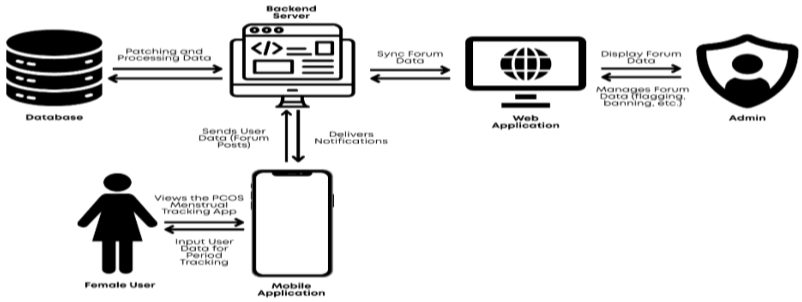

Figure 2. System Architecture

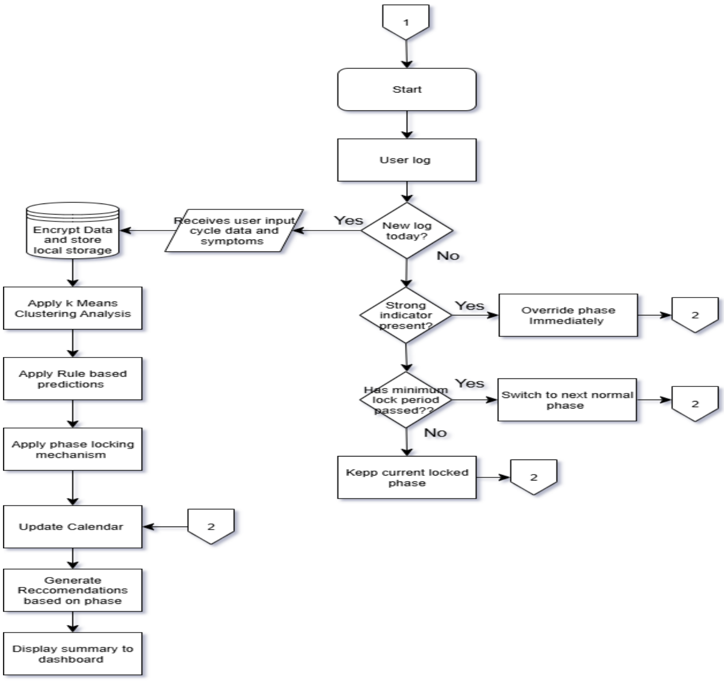

Figure 3. Algorithm Flow Chart

2.4. Core Algorithms

1. K-Means Clustering – Groups user symptom and lifestyle data into clusters representing menstrual phase patterns.
2. Rule-Based Logic – Maps clusters to menstrual phases using predefined medical conditions and thresholds.
3. Phase Locking Mechanism – Prevents frequent phase switching by enforcing a minimum duration before transitions.

Table 1. Summary of Each Algorithm Concept

Algorithm Component	Description	Purpose
K (Clusters)	Number of groups (e.g., 4 phases)	Represents menstrual phases
Distance Metric	Euclidean	Determines similarity of symptom data
Rule-based Conditions	IF-THEN logic based on medical thresholds	Phase prediction
Phase Lock Duration	Minimum phase time before switching	Prevents false transitions

2.4.1. K-Means Clustering Implementation

To accurately predict menstrual phases based on irregular symptom patterns, the system utilizes the K-Means clustering algorithm. The implementation follows a structured four-step process:

1. Data Preprocessing and Normalization User inputs vary significantly in scale (e.g., body temperature in degrees Celsius vs. symptom severity on a 1-5 scale). To ensure all features contribute equally to the distance calculation, the system applies Min-Max Normalization to scale all input vectors to a range of [0, 1]. This prevents features with larger magnitudes, such as cycle length, from dominating the Euclidean distance metric.

2. Cluster Initialization The algorithm utilizes the K-Means++ initialization method rather than random initialization. This technique selects initial cluster centers that are distant from one another, effectively reducing the probability of the algorithm converging to a suboptimal local minimum and ensuring faster convergence during the training phase.

3. Determination of k Value The number of clusters, denoted as k, is fixed at k=4. This value was selected based on domain knowledge to align with the four distinct biological phases of the menstrual cycle:

    a. Cluster 1: Menstrual Phase
    b. Cluster 2: Follicular Phase
    c. Cluster 3: Ovulation Phase
    d. Cluster 4: Luteal Phase

4. Iteration and Convergence Criteria The algorithm iteratively assigns data points to the nearest centroid using Euclidean Distance as the similarity measure. Centroids are recalculated as the mean of all points within the cluster. The process repeats until the convergence criteria are met, either the centroids do not shift by more than a threshold of $\epsilon=1\times10^{-4}$, or the algorithm reaches a maximum of 300 iterations.

2.4.2. Equations

K-Means uses Euclidean Distance to determine the similarity between a data point xix_ixi and a cluster centroid μj\mu_jμj:

$$d(x_i, \mu_j) = \sqrt{\sum_{k=1}^{n}(x_{ik} - \mu_{jk})^2}$$

Equation 1. Distance Calculation (Bishop, 2006)

Next, this equation assigns each user to the cluster whose centroid is closest. It ensures that similar symptom patterns are grouped together. The algorithm evaluates distances calculated in Equation 3.5 and selects the minimum value, forming the basis for creating meaningful clusters that reflect actual menstrual behavior trends.

$$C_i = \arg\min_j \ d(x_i, \mu_j)$$

Equation 2. Cluster Assignment (MacQueen, 1967)

K-Means minimizes the total within-cluster variance and this equation measures the total error

$$J = \sum_{j=1}^{k} \sum_{x_i \in C_j} d(x_i, \mu_j)^2$$

Equation 3. Objective Function (Hartigan, 2023)

within all clusters by summing the squared distances of each point to its centroid. The goal of K-Means is to minimize this value, meaning the clusters become tighter and more accurate. A lower objective function indicates better-defined symptom behavior groupings.

2.5. Security Features

To ensure data privacy, Evelune implements:

- AES-256 local encryption for stored data.
- Firebase Authentication with Multi-Factor Authentication (MFA).
- Role-Based Access Control through Firestore.
- HTTPS-secured API communication compliant with the Data Privacy Act of 2012.

2.6. Evaluation Metrics

Table 2. Compilation / Summary of Evaluation Metrics and Tools Used

Research Objective	**Evaluation Method**	**Evaluation Metrics / Tools Used**
Objective 1: To determine the accuracy and validity of Evelune’s menstrual phase prediction using K-Means clustering and rule-based logic	System Evaluation	Confusion matrix, accuracy, precision, recall, F1-score, user feedback through survey
Objective 2: To evaluate the security, privacy protection, and data handling practices of the application	Expert Review & ISO Assessment	ISO/IEC 25010 Security criteria, authentication review, data protection checks, IT expert feedback
Objective 3: To assess the effectiveness, clarity, and usefulness of the Educational Hub	User Survey	ISO/IEC 25010 usability indicators, content relevance rating, clarity and usefulness score, user satisfaction

The Evaluation Metrics Methods Table outlines how each research objective was assessed using specific tools and criteria. Objective 1 was evaluated through accuracy metrics and user feedback, Objective 2 through security reviews and ISO standards, and Objective 3 through user ratings of the Educational Hub’s clarity, relevance, and usefulness.

Evaluation followed ISO/IEC 25010:2023, focusing on five quality criteria:

- Functional Suitability
- Performance Efficiency
- Usability
- Reliability
- Security

A 4-Point Likert scale (1–4) was used for participant evaluation, and results were analyzed using descriptive statistics.

2.7. Ethical Considerations

All participant data were anonymized and collected with informed consent. The app adhered to privacy-by-design principles, ensuring compliance with Philippine data protection standards.

3. Results and Discussions

This section details the technical design, development process, and evaluation methods used to build Evelune. It explains the research design, system architecture, algorithms implemented, security framework, and evaluation criteria aligned with software quality standards.

3.1. System Testing

The system underwent multiple rounds of functional and logic validation. Manual and emulator-based testing confirmed that all modules performed as expected, including clustering output and rule-based prediction logic.

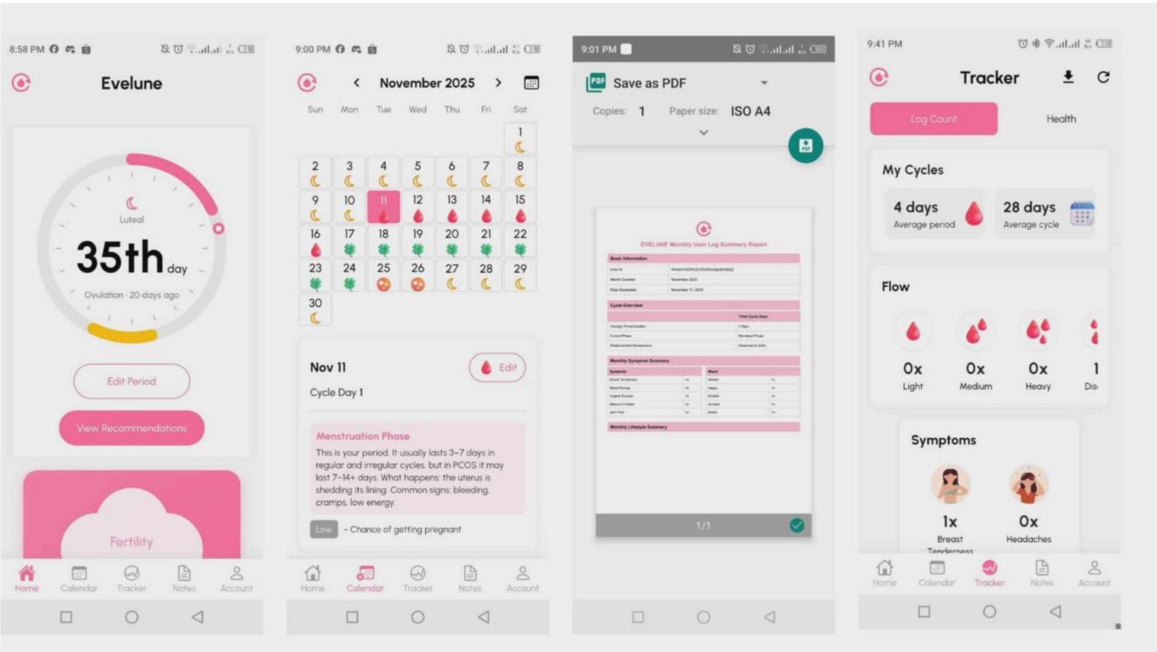

Figure 4. Menstrual Prediction Feature

Figure 4 shows the system's output, presenting the predicted menstrual phase and supporting indicators (e.g., mood, flow) based on daily logs. This interface translates the background algorithmic analysis into a clear, user-friendly prediction.

Table 3. Predicted vs Actual Menstrual Phase

Actual \ Predicted	Menstrual	Follicular	Ovulation	Luteal	**Total**
Menstrual (38)	**30**	4	1	3	38
Follicular (37)	3	**27**	5	2	37
Ovulation (37)	1	4	**27**	5	37
Luteal (38)	4	2	3	**29**	38
TOTAL	38	37	36	39	**150**

3.1.1. Menstrual Phase Prediction Confusion Matrix

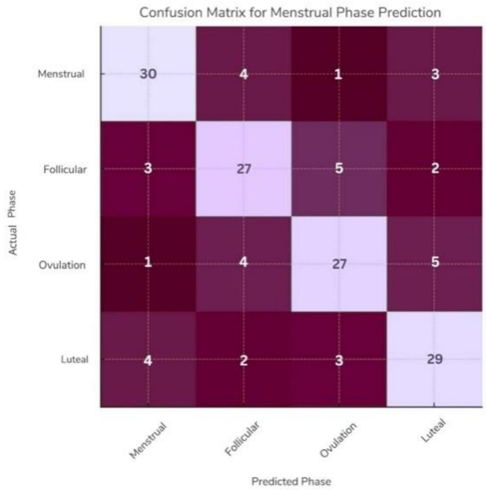

Figure 5.Confusion Matrix for Menstrual Phase Prediction

Figure 5 displays the confusion matrix for 150 respondents, showing strong performance with correct identifications of 30/38 Menstrual, 27/37 Follicular, 27/37 Ovulation, and 29/38 Luteal cases. Misclassifications were primarily between the Follicular and Ovulation phases due to symptomatic overlap, particularly in irregular and PCOS users. Overall, the model demonstrates reliable predictive capability across all four phases.

3.1.2. Evaluation End User ISO 2025 for Objective 1

Table 4. Evaluation for ISO 2025 of Objective 1

CRITERIA	MEAN	INTERPRETATION
Functional Suitability	3.9	Excellent
Performance Efficiency	3.8	Excellent
Usability	4.12	Excellent
Reliability	3.9	Excellent
GRAND WEIGHTED MEAN	**3.9**	**Excellent**

Table 4 shows "Excellent" end-user evaluations across all criteria, with mean scores ranging from 3.8 to 4.12 and a Grand Weighted Mean of 3.9. Usability received the highest rating, validating the system's overall functionality, efficiency, and ease of use.

3.1.3. Evaluation of the IT Professional – Objective 1

Table 5. Evaluation of the IT Professional for Objective 1

CRITERIA	MEAN	INTERPRETATION
Functional Suitability	3.1	Excellent
Performance Efficiency	3.3	Excellent
Usability	3.3	Excellent
Reliability	3.3	Excellent
GRAND WEIGHTED MEAN	**3.3**	**Excellent**

IT Professionals rated Objective 1 "Excellent" with a Grand Weighted Mean of 3.3 (Table 5). Although their scoring was stricter than that of end-users—particularly regarding Functional Suitability (3.1)—the results validate the system's core quality and performance.

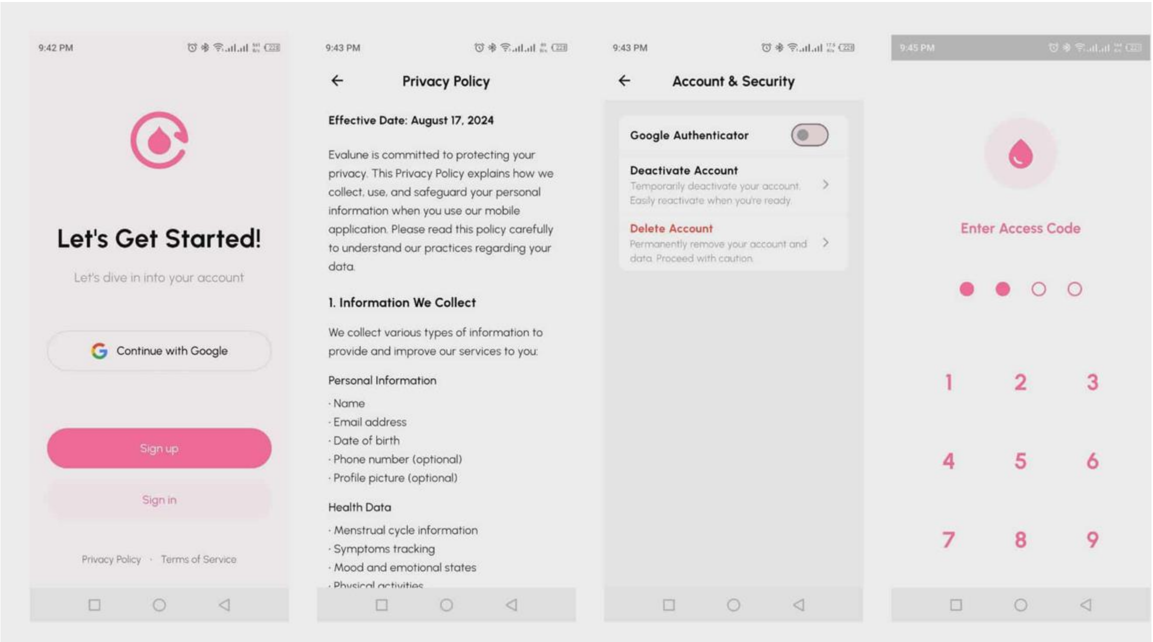

Figure 6. Objective 2 Simulation

Evelune secures sensitive data through Firebase Authentication (with optional MFA) and Firestore role-based access. As seen in Figure 6, the data at rest is encrypted using AES-256 *(via flutter_secure_storage)*, while data in transit is protected by HTTPS/TLS. These measures ensure robust security compliant with the Data Privacy Act of 2012.

Table 6. Evaluation End User for Objective 2

CRITERIA	MEAN	INTERPRETATION
Functional Suitability	3.9	Excellent
Performance Efficiency	3.8	Excellent
Usability	3.8	Excellent
Reliability	3.8	Excellent
GRAND WEIGHTED MEAN	**3.8**	**Excellent**

Table 6 reveals remarkable consistency in the IT Professionals' evaluation of Objective 2. All criteria—Functional Suitability, Performance Efficiency, Usability, and Reliability—achieved an identical mean of 3.6. This results in a Grand Weighted Mean of 3.6 and an overall "Excellent" interpretation, indicating a technically sound and well-balanced implementation.

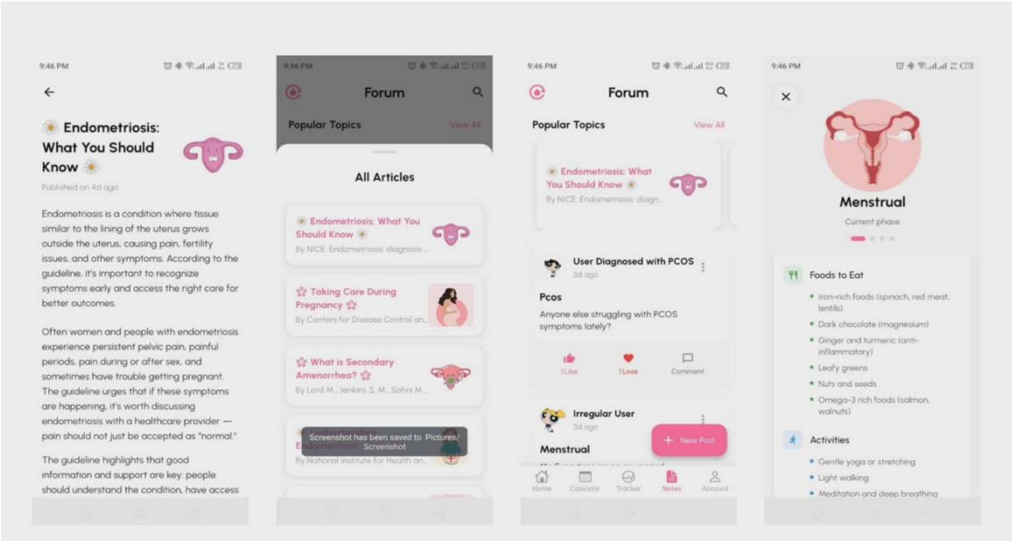

Figure 7. Simulation Testing of the App

Figure 7 illustrates the Educational Hub, which offers accessible, medically reviewed and localized content on menstrual health and PCOS. By providing articles and lifestyle tips tailored to specific cycle phases, the hub empowers users to self-educate and manage their well-being independently.

Table 7. Evaluation End User Objective 3

CRITERIA	MEAN	INTERPRETATION
Functional Suitability	3.9	Excellent
Performance Efficiency	3.9	Excellent
Usability	3.9	Excellent
Reliability	3.9	Excellent
GRAND WEIGHTED MEAN	**3.9**	**Excellent**

Table 7 shows the most uniform positive assessment for Objective 3, with all criteria—Functional Suitability, Performance Efficiency, Usability, and Reliability—receiving an identical mean of 3.9. This results in a Grand Weighted Mean of 3.9 ("Excellent"), confirming a highly balanced and unequivocal success across all critical areas as assessed by end-users.

Table 8. Evaluation IT Professional Objective 3

CRITERIA	MEAN	INTERPRETATION
Functional Suitability	3.6	Excellent
Performance Efficiency	3.6	Excellent
Usability	3.6	Excellent
Reliability	3.6	Excellent
GRAND WEIGHTED MEAN	**3.6**	**Excellent**

As shown in Table 8, Objective 3 received a uniform "Excellent" rating from IT Professionals, with every criterion scoring exactly 3.6. This consistent performance yields a Grand Weighted Mean of 3.6, providing compelling evidence of the system's high degree of technical success.

Table 9. Overall Weighted Mean Table

CRITERIA	MEAN	INTERPRETATION
Objective 1 End User	3.9	Excellent
Objective 2 End User	3.8	Excellent
Objective 3 End User	3.9	Excellent
Objective 1 IT Expert	3.3	Excellent
Objective 2 IT Expert	3.6	Excellent
Objective 3 IT Expert	3.6	Excellent
GRAND WEIGHTED MEAN	**3.6**	**Excellent**

Table 9 shows that both End Users and IT Experts rated all objectives as "Excellent." These consistent high scores confirm that Evelune effectively meets its functional and design goals, delivering a reliable, user-centered experience with strong potential for real-world use

3.2. Algorithm Performance

A total of 150 participants—divided into groups of (50) regular, (50) irregular, and (30) PCOS users—tested the application. In addition to that, 20 IT Experts making the total of 150. They evaluated features such as tracking accuracy, usability, and educational content accessibility. Average ratings indicated strong satisfaction, with most users marking “Good” to “Excellent” responses

Table 8. ISO/IEC 25010:2023 Evaluation Results

Quality Attribute	Mean Rating	Verbal Interpretation
Functional Suitability	3.85	Excellent
Usability	3.70	Good
Reliability	3.80	Excellent
Performance Efficiency	3.65	Good
Security	3.90	Excellent

3.3. Discussion

Results validate that the combination of K-Means Clustering and rule-based logic improves menstrual phase prediction accuracy for users with irregular cycles. The integration of privacy protocols and localized educational content enhances user trust and engagement. Evelune demonstrates how machine learning can personalize menstrual tracking while adhering to ethical data practices.

4. CONCLUSION

This section summarizes the project’s findings, outlines its key contributions, and discusses limitations and future improvements for the Evelune system. It highlights how the integration of AI and privacy measures advances menstrual and PCOS management.

4.1. Summary of Findings

Evelune successfully implements a system for menstrual and PCOS management that adapts to irregular cycles catering to the needs of women with PCOS and safeguards user data. It addresses limitations found in conventional menstrual tracking apps by providing accurate predictions, strong data privacy, and culturally relevant health education.

4.2. Contributions

- Integration of K-Means Clustering and rule-based phase prediction for improved personalization.
- Implementation of robust privacy and authentication mechanisms.
- Development of an educational and community platform promoting menstrual health literacy.

4.3. Limitations

The current version requires constant internet connectivity and does not yet support offline logging. The rule-based model has limited adaptability for highly irregular cycle variations.

4.4. Future Work

To enhance Evelune's inclusivity and utility, future development should expand beyond standard menstrual tracking to support diverse life stages and health conditions. Recommendations include integrating modules for pregnancy and postpartum care, as well as specialized tracking for users with HIV or chronic illnesses. The application's scope could be further broadened to include pet health monitoring, multilingual interfaces, and customizable features that adapt to individual needs. To ensure the reliability of these expansions, ongoing collaboration with healthcare professionals and specialists is essential for validating content and maintaining clinical accuracy.

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