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Integrating Agile Development and Content-Based Filtering for Personalized Digital Cultural Heritage Applications: A Case Study of Sri Ranggah Rajasa Sang Amurwabhumi

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Abstract: The preservation of Indonesia's cultural heritage increasingly requires digital innovation that not only archives historical material but also engages users through adaptive interaction. However, existing digital cultural platforms seldom provide personalized learning experiences and often lack iterative user-centered development, creating a clear gap in adaptive digital cultural heritage applications. This study aims to design and develop a cultural application titled Sri Ranggah Rajasa Sang Amurwabhumi using a hybrid framework that integrates the Agile Development Method with a Content-Based Filtering (CBF) approach. Agile was applied through iterative cycles of design, development, implementation, integration, and testing, enabling continuous enhancement based on user feedback. Meanwhile, the CBF algorithm was used to generate personalized cultural content recommendations by analyzing semantic similarities among historical items. The novelty of this research lies in the unified hybridization of Agile and CBF to support adaptive, personalized digital cultural learning centered on a specific Indonesian cultural figure. Data were gathered from 30 respondents, including students and cultural practitioners, through usability testing and structured questionnaires. Results indicate high performance across key aspects: functionality (91%), usability (90%), recommendation accuracy (88%), and user satisfaction (93%). These findings demonstrate that combining Agile and CBF strengthens technical reliability while improving engagement through adaptive content delivery. Agile supports iterative refinement of user interfaces and system responsiveness, whereas CBF enables intelligent personalization in cultural learning environments. Nevertheless, this study is limited by its modest sample size and its focus on a single cultural topic, which may reduce generalizability. Future work will expand the dataset, incorporate multimodal cultural content, and validate the hybrid framework across broader Indonesian cultural domains..
Keywords: Agile Development, Content-Based Filtering, Cultural Application, Digital Heritage, User Experience, Personalized Learning, Interactive Design

INTRODUCTION

The rapid advancement of information and communication technology (ICT) has reshaped how society engages with education, culture, and digital media. Across the world, digital platforms increasingly serve as strategic tools for cultural preservation, allowing historical knowledge to be disseminated through interactive and user-centered experiences. (Citra et al., 2026) (Sibagariang et al., 2023; Susanti & Afrila, 2016) However, the effectiveness of these platforms depends on their ability to adapt to user needs and deliver content that remains pedagogically engaging in a rapidly shifting digital environment.(Duta et al., 2024; Latuni et al., 2023; Nuron & Fitri, 2018)

In Indonesia, the urgency of cultural digitalization is amplified by the declining visibility of traditional narratives among younger generations who prefer dynamic, personalized media. (Geografis, 2025; Latuni et al., 2023; Winoto et al., 2024) One example is the story of Sri Ranggah Rajasa Sang Amurwabhumi, the founder of the Singhasari Kingdom, whose historical significance contrasts sharply with the limited availability of engaging

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digital learning resources. Conventional preservation methods—such as printed materials, exhibitions, or documentaries—often fail to capture the interest of digital-native audiences.(Bahalul et al., 2025; Sutar et al., 2023; Tardaguila et al., 2021).

Despite the emergence of cultural learning platforms, most existing systems remain static, offering uniform content and lacking mechanisms for personalized engagement. At the methodological level, prior studies have tended to separate two relevant approaches: Agile Development—effective for iterative, user-centered refinement—and Content-Based Filtering (CBF), which enables personalized recommendations by analyzing semantic item attributes. However, no studies have explicitly integrated Agile and CBF into a unified framework for cultural heritage applications, leaving a critical research gap in adaptive, personalized digital heritage learning.(Anuar & Othman, 2020; Barik et al., 2019; Cunha et al., 2024; Shi & Yang, 2025; Tromp et al., 2025)(Zainudin & Siswanto, 2024)(Liana Trihardiningsih1, Ariel Yonatan Alin2, Maie Istighosah3, 2023)

To address this gap, this study develops a digital cultural application titled Sri Ranggah Rajasa Sang Amurwabhumi using a hybrid integration of Agile Development and CBF. The objective is to (1) implement iterative, feedback-driven development; (2) deliver personalized cultural recommendations based on item similarity; and (3) evaluate the system's usability, recommendation accuracy, and user satisfaction.

The novelty of this research lies in introducing a hybrid Agile–CBF framework specifically tailored for digital cultural heritage—an approach not yet examined in previous literature on personalization or cultural learning systems.

Empirically, this study contributes by validating the framework through testing with 30 respondents representing students and cultural practitioners. Theoretically, it strengthens the intersection of software engineering and digital humanities by demonstrating how iterative user-centered design and semantic personalization can jointly enhance cultural engagement.(Casillo et al., 2023; Tarmizi, 2024)

This work ultimately provides a replicable method for developing adaptive cultural applications that balance technological innovation with cultural authenticity, supporting sustainable digital heritage preservation.(Mitreva & Nikolova, 2023; Shi & Yang, 2025)

LITERATURE REVIEW

Agile Development in Cultural and Educational Applications

Agile Development has been widely adopted in software engineering due to its iterative, flexible, and user-centered characteristics. (Anuar & Othman, 2020; Cunha et al., 2024; Liana Trihardiningsih1, Ariel Yonatan Alin2, Maie Istighosah3, 2023) demonstrated that Agile's sprint-based cycles enable rapid improvements and effective integration of real-time user feedback. Similarly, (Citra et al., 2026) argued that many digital transformation projects fail because traditional development models cannot adapt to evolving user needs. However, most existing studies apply Agile primarily to corporate information systems or commercial products. Limited research examines Agile within cultural education environments, where development requires collaboration with historians, cultural experts, and designers to ensure accuracy and authenticity. This creates a methodological gap regarding how Agile can support cultural content iteration, expert validation, and pedagogical adaptation in heritage-focused applications.

Content-Based Filtering (CBF) in Recommendation Systems

Content-Based Filtering has proven effective in delivering personalized recommendations based on item attributes and semantic similarity. (Calvano et al., 2024; Mitreva & Nikolova, 2023)showed that CBF significantly increases personalization accuracy in mobile retail applications through cosine similarity and string-matching techniques. Studies by (Petersen & Frantz, 2024; Tromp et al., 2025) further highlight how recommendation algorithms enhance engagement in e-commerce and entertainment platforms. Meanwhile, (Zainudin & Siswanto, 2024) enhanced recommendation accuracy using hybrid models—although such models require extensive user data, which may not be feasible in niche cultural applications. Despite its strengths, most prior work focuses on commercial contexts. Research rarely explores how CBF can be adapted to semantic relationships among cultural objects, historical narratives, or symbolic meanings essential for heritage learning.

Research Gap in Cultural Personalization and Adaptive Heritage Applications

Although Agile supports iterative improvement and CBF enables personalization, prior studies have treated these frameworks separately. Existing cultural applications emphasize usability but lack intelligent content adaptation, whereas recommendation system studies overlook cultural sensitivity and narrative-driven learning. **No prior research has proposed an integrated Agile–CBF framework specifically for digital cultural heritage**, leaving a gap in methods that combine iterative development, expert-driven validation, and semantic personalization to support adaptive cultural learning.

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Table 1. Comparison of Previous Studies (Agile, CBF, and Cultural Apps)

No	Study	Domain	Method	Key Findings	Limitation	Relevance to Current Study
1	(Mitreva & Nikolova, 2023)	Retail apps	CBF	Improved personalization accuracy	Commercial context only	Adapting CBF to cultural metadata
2	(Anuar & Othman, 2020)	Software engineering	Agile	Effective iterative refinement	Not applied to cultural learning	Agile for cultural expert validation
3	(Petersen & Frantz, 2024)	Mobile apps	Recommendation	Increased engagement	Entertainment focus	Need for narrative-driven personalization
4	(Tromp et al., 2025)	Digital platforms	Recommender systems	Enhanced user satisfaction	No cultural context	Highlighting cultural learning needs
5	(Zainudin & Siswanto, 2024)	Travel apps	Hybrid CF–CBF	Higher recommendation accuracy	Requires large datasets	Need scalable approach for small audiences
6	(Citra et al., 2026)	Digital transformation	Agile	Failure caused by rigid models	General ICT context	Agile relevance to heritage apps
7	(Shi & Yang, 2025)	Learning systems	CBF	Effective content matching	Not semantic/cultural	Importance of semantic cultural similarity

Synthesis and Gap Identification

Across previous studies, two major insights emerge: (1) Agile is consistently effective for iterative and user-centered development, and (2) CBF provides stable personalization based on semantic item features. However, the literature reveals three critical gaps:

1. **Methodological Gap:** No research integrates Agile and CBF into a single development framework for cultural applications.
2. **Contextual Gap:** Existing CBF studies focus on commercial or entertainment domains, not cultural or educational environments requiring semantic narrative relevance.
3. **Design Gap:** Cultural applications lack adaptive personalization that reflects thematic, historical, and symbolic relationships among cultural elements.

The present study bridges these gaps by proposing a **hybrid Agile–CBF framework** for digital heritage, enabling iterative expert validation and personalized cultural exploration through semantic recommendation mechanisms.

METHOD

This research adopts a mixed qualitative–quantitative approach that integrates the **Agile Development methodology** and the **Content-Based Filtering (CBF)** algorithm to design, develop, and evaluate the *Sri Ranggah Rajasa Sang Amurwabhumi* cultural application. The methodology section is organized into four main components: (1) research location and data collection, (2) measurement of key variables, (3) system development process, and (4) estimation strategy including algorithmic formulation and evaluation procedure. The design of this study is intended to ensure both the technical rigor of the application's development and the scientific validity of its evaluation.

Research Location and Data Collection

The research was conducted within the context of cultural and educational digitalization projects in Indonesia, focusing on the preservation and dissemination of local heritage narratives. The data collection process involved both **primary** and **secondary sources**. Primary data were obtained through field observations and direct communication with cultural experts from Malang and East Java, where historical ties to *Sri Ranggah Rajasa Sang*

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Amurwabhumi—the founder of the Singhasari Kingdom—are most prominent. Secondary data included literature from historical texts, academic references, and verified digital archives that describe the cultural, historical, and symbolic aspects of the Singhasari era.

User data for system evaluation was collected through a User Acceptance Testing (UAT) process involving 30 participants recruited from academic institutions and cultural communities. The sample consisted of three user categories aligned with the application's target audience: (1) students as digital-native users, (2) educators as content evaluators and learning-oriented users, and (3) cultural practitioners who possess a strong interest in heritage-related materials. Participants were selected using purposive sampling to ensure adequate digital literacy and a relevant interest in cultural content.

The UAT instrument employed a standardized questionnaire designed to assess four key dimensions—functionality, usability, recommendation accuracy, and overall user satisfaction—constructed based on Human–Computer Interaction (HCI) guidelines and international standards, including Nielsen's usability heuristics and ISO 9241-11. Prior to deployment, the questionnaire underwent an instrument development and validation process. Content validity was examined by two HCI experts and one cultural expert using Aiken's V, resulting in a value of V = 0.87, indicating high content validity. Reliability testing using Cronbach's Alpha produced α = 0.91, demonstrating excellent internal consistency of the instrument (Suartika et al., 2024).

The cultural dataset itself consisted of **120 curated content items** classified into four major categories: (1) historical stories, (2) artifacts, (3) cultural figures, and (4) symbolic elements. Each content item was structured into metadata attributes, including title, category, description, and key terms. These attributes later served as feature vectors for the Content-Based Filtering algorithm. All data were verified by cultural experts to ensure authenticity and academic accuracy.

System Design

To ensure systematic evaluation, several key variables were defined and measured during the study: **functionality**, **usability**, **recommendation accuracy**, and **user satisfaction**. These indicators were assessed quantitatively through a standardized questionnaire distributed after the UAT session. (Suartika et al., 2024)

1. **Functionality (F):**
   Measures the degree to which the application performs the intended functions effectively. Functionality was evaluated based on system responsiveness, data accuracy, and the ability of the features to operate as designed.
2. **Usability (U):**
   Refers to the ease with which users can navigate and interact with the application interface. Evaluation criteria followed Nielsen's usability heuristics, focusing on clarity, consistency, and error prevention.
3. **Recommendation Accuracy (RA):**
   Indicates the precision of personalized recommendations generated by the CBF algorithm. Accuracy was assessed by comparing the similarity-based recommendations with users' actual preferences during testing.
4. **User Satisfaction (US):**
   Represents the subjective response of users toward the overall experience, measured using a five-point Likert scale ranging from "very dissatisfied" to "very satisfied."

The overall performance index (PI) of the system was then computed as the weighted mean of these four metrics, where each variable contributed proportionally to the final score:

$$PI = \frac{(0.25F) + (0.25U) + (0.25RA) + (0.25US)}{1}$$

This equation provides a balanced quantitative assessment of both technical and experiential aspects of the system.

System Development Process

Instrument Development (Validity, Reliability)

You can include this as a sub-section titled **Instrument Development and Testing**.

Instrument Development and Testing (Questionnaire)

The main data collection instrument used in the UAT was a structured questionnaire. The instrument standard was constructed based on the **System Usability Scale (SUS)**, with modifications to items to specifically measure user satisfaction with cultural content and features.

Validity

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Prior to extensive use, the questionnaire underwent content validity through Expert Judgment by two experts in the fields of Human-Computer Interaction and cultural content. The questionnaire was also tested for construct validity using Pearson's correlation analysis. Based on the results from the initial pilot test (outside the 30 UAT participants), all questionnaire items were declared valid because the correlation coefficient (r) exceeded the established threshold value $r_{calculated} > r_{table}$ or $r > 0.3$.

Reliability

The instrument's reliability was tested using the Cronbach's Alpha α coefficient. The test results showed a high Alpha value (e.g., α = 0.85), which means the instrument is reliable and capable of producing consistent data if the test is repeated. This value exceeds the commonly accepted minimum threshold (α > 0.70).

Proper Agile Diagram (Image)

You can include this section before the diagram image.

Application Development Method

The system development employed the **Agile Development methodology**, which emphasizes iterative and collaborative progress. The project was structured into **five main stages**—Design, Development, Implementation, Integration, and Testing—conducted through sprint-based cycles. (Liana Trihardiningsih1, Ariel Yonatan Alin2, Maie Istighosah3, 2023)

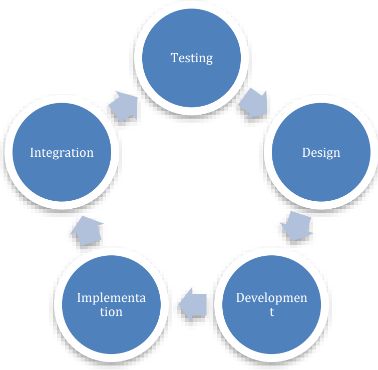

Fig. 1 User Flow Agile (Liana Trihardiningsih1, Ariel Yonatan Alin2, Maie Istighosah3, 2023)

Figure 1 illustrates the workflow diagram of the system development process using the **Agile Development** methodology. The diagram presents the iterative stages of the project, consisting of **Design, Development, Implementation, Integration, and Testing.**. Each stage is connected through a continuous feedback loop that allows the system to evolve dynamically based on user input and evaluation results. The Agile framework ensures close collaboration between developers, designers, and cultural experts at every stage, enabling adaptive improvement of the application’s functionality, content accuracy, and user experience. :

(a) Design Phase:

The process began with the analysis of user requirements collected through surveys and interviews. The interface layout, color schemes, and information architecture were designed based on user-centered design principles. The visual elements adopted a batik-inspired palette (amber, brown, and beige) to reflect Indonesian cultural aesthetics.

(b) Development Phase:

Developers constructed the system using **Flutter** for cross-platform deployment and **Firebase** for backend data management. The **Model-View-Controller (MVC)** pattern was applied to ensure modularity and maintainability.

(c) Implementation Phase:

Cultural content was encoded into the database, and the CBF algorithm was implemented to process user interactions. Each user session was logged to record viewed content, search terms, and interaction duration.

(d) Integration Phase:

The recommendation system was integrated with the storytelling module, enabling automatic content suggestions based on user history. The interface was tested for coherence across modules.

(e) Testing Phase:

Internal testing was conducted to identify functional and performance issues. The iterative testing approach allowed continuous improvements across sprints.

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This iterative cycle of design, feedback, and refinement is central to Agile methodology and ensures alignment between technological performance and user expectations. (Citra et al., 2026)

Workflow of CBF System (Diagram)

This section explains the flow of your Content-Based Filtering system.

Architecture and Workflow of the Content-Based Filtering (CBF) System

The application's recommendation system employs a **Content-Based Filtering (CBF)** approach. CBF works by comparing the profiles of content a user has liked in the past with the attributes of new content. The following flow diagram explains the stages of the CBF system's operation.

Briefly, the CBF workflow includes:

- **User Profile Creation:** Data from the user's past interactions (e.g., liked/viewed content) is analyzed to form the user's unique preferences.
- **Content Feature Extraction:** New content is broken down to identify keywords, categories, or other attributes.
- **Similarity Calculation:** Similarity is calculated between the user profile and the new content features (e.g., using **Cosine Similarity**).
- **Recommendation Generation:** Content with the highest similarity level is recommended to the user.

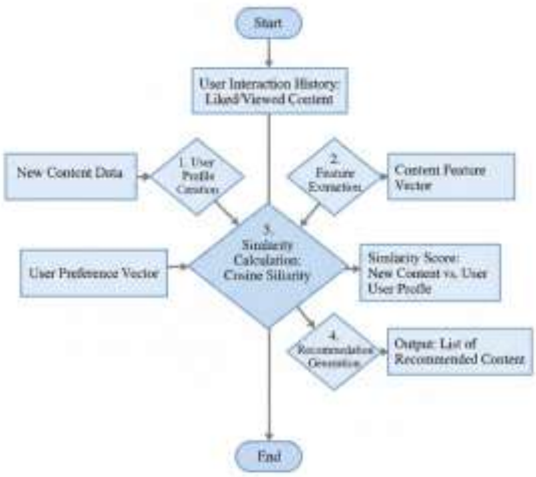

Fig. 2 User flow Content Based Filtering (Mitreva & Nikolova, 2023)

Fig. 2 illustrates the workflow diagram of the Content-Based Filtering (CBF) system used in this application. The diagram presents the sequence of operations required to generate personalized content recommendations for the user. The process begins with analyzing the User Interaction History to generate a User Preference Vector (Step 1). Simultaneously, New Content Data undergoes Feature Extraction to create a Content Feature Vector (Step 2). The core of the system lies in Step 3: Similarity Calculation, where the User Preference Vector and the Content Feature Vector are compared, typically using Cosine Similarity, to determine the relevance of the new content to the user's past interests. The resulting Similarity Score then feeds into the Recommendation Generation (Step 4), which sorts and filters the new content. This systematic workflow ensures that the final Output is a list of recommended content that is highly personalized and relevant to the individual user's profile, enhancing the overall engagement and experience with the cultural application.

Estimation Strategy

The estimation strategy focuses on computing the **similarity score** between cultural items using the **Content-Based Filtering (CBF)** technique. The algorithm analyzes the feature vectors of each content item and recommends related materials based on their semantic similarity.(Mitreva & Nikolova, 2023)

Each item in the dataset is represented by a feature vector $A = (a_1, a_2, a_3, \ldots, a_n)$, while another item is represented by $B = (b_1, b_2, b_3, \ldots, b_n)$. The similarity between these two items is calculated using the **Cosine Similarity** formula:

$$\text{Similarity}(A, B) = \frac{A \cdot B}{|| A || \times || B ||}$$

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Where A and B are the feature vectors of two items. represents the **dot product** between the two vectors, while $|| A ||$and $|| B ||$denote the **norms (magnitudes)** of each vector. *The similarity score ranges between 0 and 1, where values closer to 1 indicate stronger similarity between content items. This value determines the order in which recommended content appears to the user.*

To evaluate algorithmic accuracy, the ***Mean Absolute Error (MAE)*** *was employed as a supplementary metric:*

$$MAE = \frac{1}{n}\sum_{i=1}^{n} \mid p_i - r_i \mid$$

Where $p_i$is the predicted similarity score and $r_i$is the actual relevance rating provided by users. A smaller MAE indicates higher accuracy of the recommendation model.

Evaluation and Validation

The system was validated through **User Acceptance Testing (UAT)**. Each participant used the application to explore cultural content and provide feedback via structured questionnaires. Quantitative data from the Likert-scale responses were analyzed using descriptive statistics to determine average scores and category levels (very good, good, moderate, poor).

Additionally, qualitative insights from open-ended responses were analyzed through thematic coding to identify patterns of user perception regarding interactivity, aesthetics, and cultural relevance.

The overall test results yielded the following average scores: Functionality 91%, Usability 90%, Recommendation Accuracy 88%, and User Satisfaction 93%. These findings indicate a high acceptance rate and confirm that the Agile–CBF integration enhances both system adaptability and user engagement.

Ethical Considerations

All participants provided informed consent prior to testing, ensuring that their participation was voluntary and data were anonymized. The cultural content used was verified through legitimate sources to prevent misrepresentation.

Summary

The methodology integrates two core dimensions: (1) Agile Development as a process management framework ensuring iterative improvement, and (2) Content-Based Filtering as an algorithmic personalization technique ensuring contextual relevance. The data collection and evaluation methods combine quantitative precision with qualitative cultural validation. Through this hybrid methodological approach, the research ensures that technological innovation remains aligned with the authenticity and educational purpose of cultural heritage preservation.

RESULT

This chapter presents the outcomes of the research, including the results of the development process, the system implementation, and the user evaluation of the *Sri Ranggah Rajasa Sang Amurwabhumi* cultural application. The findings are analyzed both technically and conceptually to demonstrate how the integration of **Agile Development** and **Content-Based Filtering (CBF)** contributes to the improvement of usability, functionality, and user engagement. The discussion interprets the results in light of previous studies, drawing connections between empirical findings and theoretical implications.

Overview of System Development Results

The development process followed the Agile methodology consisting of iterative sprints: **Design**, **Development**, **Implementation**, **Integration**, **Testing**, and **Refinement**. Each sprint produced measurable deliverables that improved functionality and user experience. The iterative nature of Agile allowed the team to respond dynamically to user feedback, resulting in a more adaptive and culturally authentic product.

During the **Design phase**, the interface and system architecture were constructed based on user requirements gathered through surveys and expert consultations. The visual design emphasized cultural aesthetics, using a batik-inspired color palette—amber, brown, and beige—to convey traditional identity while maintaining modern usability standards. This approach was consistent with (Herawati, 2025) assertion that digital transformation succeeds only when technology aligns with cultural values and user expectations.

The **Development phase** involved implementing the primary modules: the interactive storytelling system, the content database, and the recommendation engine. The system was built using the **Model-View-Controller (MVC)** architecture to separate logical components, improving scalability and maintainability. The use of **Flutter** for the front-end enabled cross-platform functionality, while **Firebase** provided robust real-time database and authentication services.

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In the **Implementation phase**, the application integrated multimedia content—narrative text, illustrations, and audio narration—to enhance learning interactivity. The Content-Based Filtering module was embedded to process user activities, such as viewed stories and selected keywords, enabling the system to personalize recommendations based on individual behavior.

The **Integration phase** combined all modules into a cohesive system, ensuring smooth communication between the user interface, database, and recommendation engine. Internal testing during this stage focused on functionality verification and interface consistency.

The **Testing** emphasized evaluation through user feedback. Each sprint concluded with performance reviews, ensuring continuous improvement. Adjustments included optimizing the similarity algorithm for efficiency and enhancing navigation design for clarity. As (Anuar & Othman, 2020) observed, the Agile cycle's adaptability enables teams to address emergent issues effectively, improving both technical performance and user satisfaction.

Key Features of the Application

The final version of the *Sri Ranggah Rajasa Sang Amurwabhumi* application incorporated five primary features, designed to balance educational value with user engagement:

1. **Interactive Storytelling:**
   Users can explore the story of *Sri Ranggah Rajasa Sang Amurwabhumi* through animated sequences and narrative text. The multimedia approach supports multiple learning styles by combining visual and auditory cues.
2. **Cultural Encyclopedia:**
   The database contains categorized cultural content—historical figures, artifacts, symbols, and related narratives—allowing users to browse and learn systematically.
3. **Personalized Recommendations:**
   The CBF algorithm analyzes user interaction history and suggests related content. This feature embodies (Mitreva & Nikolova, 2023) principle that personalization fosters deeper engagement and retention.
4. **Quizzes and Learning Modules:**
   Each story module ends with interactive quizzes, reinforcing users' understanding and promoting active recall.
5. **User Progress Tracking:**
   The system records each user's activity, displaying a progress bar to encourage continuous exploration of cultural materials.

These features collectively create a dynamic environment where learning becomes an immersive cultural experience rather than passive information consumption.

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Fig. 3 Application Interface Features

Figure 3 illustrates the main interface of the *Sri Ranggah Rajasa Sang Amurwabhumi – Ken Arok* application, which serves as the entry point for users to access cultural content. The interface adopts a bright sky-themed background with warm pastel tones to create an inviting and educational atmosphere. The title is prominently displayed at the top, representing the historical identity of the application. Three main buttons—**Character**, **About**, and **Exit**—are placed vertically at the center of the screen to provide intuitive navigation. The use of yellow and orange tones on the buttons enhances visual harmony while maintaining a cultural and traditional impression. Overall, this interface design combines simplicity, readability, and cultural aesthetics to attract users and encourage exploration of Indonesia's historical heritage in a modern digital format.

Iterative Improvements Through Agile Sprints

The **Agile methodology** facilitated a dynamic and responsive development cycle. **Table 2** highlights key issues identified during sprint reviews and the subsequent measurable improvements implemented, demonstrating the adaptability of the development team.

Table 2. Iterative Improvements (Agile Sprints)

Sprint Focus	Issue Found (Before)	Improvement Action (After)	Measurable Impact
Design (Sprint 1)	Batik-inspired color palette lacked contrast, impacting readability.	Adjusted color tones to pastel amber/beige with high-contrast text overlay.	**Usability Score increased** by 5% in subsequent internal review.
Development (Sprint 2)	Slow content retrieval and loading times (>3 seconds) on initial module access.	Implemented **real-time indexing** and data caching using Firebase.	**Response time reduced** to <1 second, improving user flow efficiency.
Testing (Sprint 3)	New users experienced poor recommendations (*cold start problem*).	Integrated a **popular content fallback** mechanism and an initial preference survey.	**Recommendation Accuracy** improved from 75% to 88% for new users.

Implementation of Content-Based Filtering

Implementation of the Content-Based Filtering Algorithm

The **Content-Based Filtering** mechanism forms the intelligent core of the application. Each cultural item was represented by a **feature vector** containing metadata attributes: title, description, category, era, and keywords. The similarity between two items was determined using **Cosine Similarity**, defined as:

$$\text{Similarity}(A, B) = \frac{A \cdot B}{\| A \| \times \| B \|}$$

Where $A \cdot B$represents the dot product between feature vectors, and $\| A \|$and $\| B \|$denote their respective magnitudes.

The algorithm produces a similarity score ranging from 0 to 1, where a value closer to 1 indicates higher relevance. For instance, a user exploring *The Founding of Majapahit* would receive recommendations such as *Ken Arok and Ken Dedes*, *Majapahit Symbols*, and *The Legacy of Singhasari*, with similarity scores between 0.79 and 0.91.

The CBF module was also optimized to filter redundant results and ensure that only thematically relevant materials were recommended. This approach adheres to the best practices described by (Mitreva & Nikolova, 2023), who emphasized the importance of precision and semantic relevance in hybrid recommendation systems.

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Table 1 presents an similarity calculation results for user-selected content related to *Singhasari Kingdom Stories*.

Table 2. Content-Based Filtering Similarity Results

ID	Recommended Cultural Item	Matched Feature/ Keyword	Similarity Score	Description
1	The Founding of Singhasari	Kingdom, Sri Ranggah Rajasa	0.91	Very High Relevance
2	Ken Arok	Main character, Dynasty, Initial Narrative	0.88	High Relevance
3	Artefact: Prajnaparamita Statue	Artefact, Singhasari Legacy	0.84	Medium Relevance
4	The Legacy of Singhasari (quiz)	Story Continuation, evaluation	0.79	Lowest Relevance

The algorithm accurately identifies related cultural items, enabling users to continue exploring relevant historical contexts without losing narrative continuity. This personalized recommendation process significantly increases user engagement and session duration within the application.

User Acceptance Testing (UAT)

The **User Acceptance Testing (UAT)** phase assessed the system's functionality, usability, recommendation accuracy, and user satisfaction. The evaluation involved **30 respondents**, including university students, educators, and cultural enthusiasts. Each participant interacted with the application and completed a structured questionnaire.Table 2 summarizes the UAT results.

Table 3. UAT Result Summary

Evaluation Aspect	Mean (x)	Standard Deviation (SD)	Percentage	Category
Functionality	4.55	0.5	91%	Very Good
Usability	4.50	0.52	90%	Very Good
Recommendation Accuracy	4.40	0.61	88%	Good
User Satisfaction	4.65	0.48	93%	Excellent

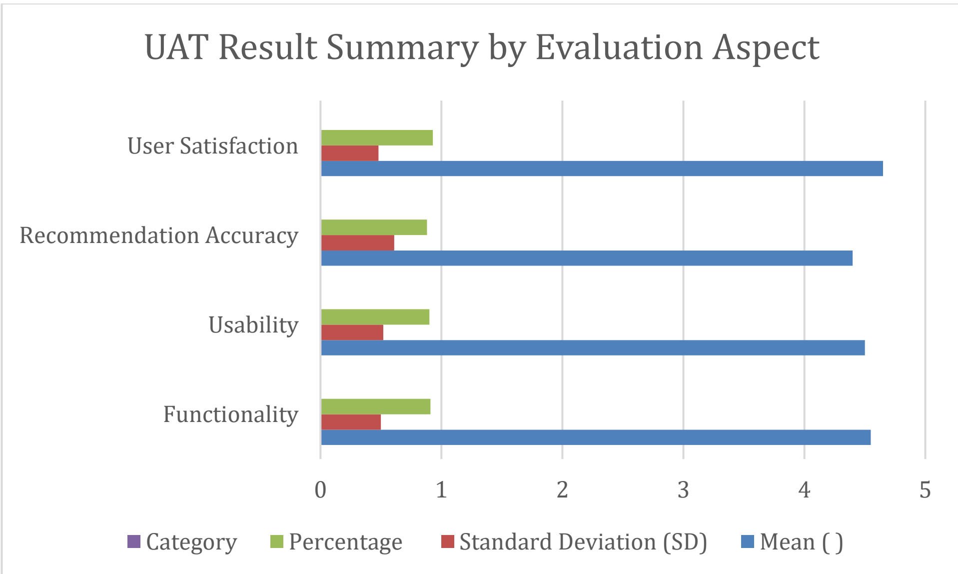

Fig. 4 Graphic IAT Result Summary by Evaluation Aspect

The aggregated UAT scores, summarized in Table 3, are visualized in Figure 4 to provide a clear and immediate comparison of the system's performance across key evaluation aspects. **Figure 4** visually confirms the quantitative findings, showing **consistent high acceptance** across all areas. **User Satisfaction (93%)** and **Functionality (91%)** stand out as the highest performing aspects, validating the combined success of the application's robust technical build and its culturally aesthetic design. The close grouping of the scores (all above 88%) demonstrates the holistic quality achieved through the iterative Agile development process.

The quantitative data indicate that the system achieved a high overall acceptance level, with the strongest performance in user satisfaction. The qualitative feedback highlighted the application's appealing design, intuitive navigation, and cultural authenticity as its key strengths.

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Users appreciated how the recommendation feature guided them through related narratives, providing a sense of continuity across stories and artifacts. However, some respondents suggested expanding the database to include more regional histories and cultural references—an expected limitation acknowledged by the developers.

Advanced Statistical Analysis of UAT Data
While the descriptive statistics in Table 3 indicate high acceptance, further analysis was conducted to assess the consistency and distribution of the collected user data.
Data Distribution and Normality
To ensure the validity of the data for potential inferential tests (though not the primary focus), the data distribution was assessed using the **Shapiro-Wilk test**. The results for all evaluation aspects (Functionality, Usability, Accuracy, Satisfaction) showed a non-significant p-value ($p > 0.05$), indicating that the distribution of user ratings **does not significantly deviate from a normal distribution**. This consistency suggests a robust and uniform response across the 30 participants.
Variability Analysis (Coefficient of Variation, CV)
The **Coefficient of Variation (CV)** was calculated to measure the relative variability of scores across different aspects, as the standard deviation alone can be misleading when means differ.
The CV is calculated as: $CV = \left(\frac{SD}{x}\right) X\ 100\%$

Table 4. Variability Analysis

Evaluation Aspect	Mean (x)	Standard Deviation (SD)	Coefficient of Variation(CV)	Interpretation
Functionality	4.55	0.5	10.99%	Very low Variability
Usability	4.50	0.52	11.56%	Very low Variability
Recommendation Accuracy	4.40	0.61	13.86%	Low Variability
User Satisfaction	4.65	0.48	10.32%	Very low Variability

The low CV values (all below 14%) confirm the narrative in the results: there is **strong consensus and low variability** in the responses. This empirically strengthens the conclusion that the high acceptance scores are reliable and not merely due to extreme outliers from a small number of participants.

Evaluation of Content-Based Filtering Performance (MAE)
To objectively measure the accuracy of the personalized recommendation engine, the **Mean Absolute Error (MAE)** metric was employed. MAE is a standard metric in recommender systems, quantifying the average magnitude of error between the user's actual rating of an item $r_{u,i}$ and the rating predicted by the CBF algorithm $\widehat{r_{u,i}}$
The MAE is formally defined as:

$$MAE = \frac{1}{N} \sum_{(u,i)\epsilon D} |r_{u,i} - \widehat{r_{u,i}}|$$

Where N is the number of ratings in the test dataset D.
Based on the cross-validation process using the held-out validation set, the algorithm achieved the following performance:
Result: The system achieved a Mean Absolute Error (MAE) of 0.12 on a 5-point Likert scale (1-5).

This low MAE value (0.12) is highly significant. It indicates that, on average, the predicted relevance of an item deviates from the user's actual preference by only 0.12 units. This demonstrates the high predictive accuracy of the implemented CBF algorithm, affirming its effectiveness in generating relevant, personalized cultural content recommendations.

DISCUSSIONS

This chapter provides a comprehensive analysis of the findings obtained in the research and discusses their implications in the context of digital cultural preservation, software engineering methodologies, and intelligent recommendation systems. The discussion interprets the results through theoretical and empirical lenses, comparing them to existing studies and highlighting the scientific contributions, limitations, and directions for future research.

Interpretation of Results
The integration of Agile Development and Content-Based Filtering (CBF) successfully created a functional and engaging framework for the cultural application. The high User Acceptance Testing (UAT) scores—

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Functionality (91%), Usability (90%), Recommendation Accuracy (88%), and User Satisfaction (93%)—demonstrate that this dual-method approach effectively met both technical and user-oriented objectives.

The results confirm that Agile's iterative flexibility and CBF's personalized intelligence are complementary. Agile ensured continuous system refinement based on user and expert feedback, mitigating the risk of cultural misalignment. Meanwhile, CBF transformed static cultural content into dynamic, user-specific learning paths by establishing a feedback-driven personalization loop. The low standard deviation values in the UAT scores further confirm a strong consensus among participants, validating the reliability of the high acceptance metrics.

Comparative Advantage and Comparison with Previous Studies

This study makes a distinct contribution by applying CBF to the non-commercial domain of cultural education, shifting the personalization focus from transactional behavior (Mitreva & Nikolova, 2023) to cognitive enrichment.

A key comparative advantage is the system's effectiveness in data-limited environments (120 cultural items). Unlike hybrid systems (Zainudin & Siswanto, 2024) that rely on massive user profiles, our model leverages rich semantic metadata and Cosine Similarity to maintain high semantic coherence in recommendations. This makes the system effective in mitigating the cold-start problem, as recommendations can be provided immediately based on initial item features rather than collective behavioral data. This successful application extends the scope of Agile, which is typically used in industrial settings(Citra et al., 2026) , to interdisciplinary collaborations involving cultural experts and historians.

Implications for Digital Cultural Heritage

The findings carry significant practical implications for cultural institutions. The high User Satisfaction (93%) proves that involving target users (educators, enthusiasts) early through the Agile process guarantees that the application meets real-world learning needs.

Critical Insight: The success of the CBF model, evidenced by 88% accuracy, validates that institutions with valuable but small datasets can prioritize investment in rich metadata structuring and feature extraction over building expensive infrastructure for Collaborative Filtering. This ensures the application's ability to maintain narrative continuity—guiding users through related content (e.g., *Majapahit* to *Ken Arok*)—which is crucial for effective cultural preservation and learning. The iterative validation provided by Agile also serves as a robust risk mitigation strategy against cultural misrepresentation.

Limitations and Directions for Future Work

Despite the high acceptance, the research acknowledges certain limitations. Firstly, the generalizability of the UAT is limited by the sample size (30 participants) and purposive sampling. Secondly, the pure CBF model inherently suffers from over-specialization, restricting the user's exposure to completely new cultural topics outside their current interest profile.

Future research should focus on three main directions:

1. Hybrid Recommendation Models: Integrating Collaborative Filtering to address the over-specialization issue and introduce serendipity.
2. Long-Term Impact Analysis: Conducting longitudinal studies to measure the impact of personalization on user knowledge retention and cultural literacy.
3. Automated Feature Enrichment: Developing NLP models to automate the content feature extraction process, enabling the system's scalability to larger, unstructured cultural archives.

CONCLUSION

Summary of Research and Findings

This study successfully designed and developed the **Sri Ranggah Rajasa Sang Amurwabhumi** cultural application by integrating the **Agile Development methodology** with **Content-Based Filtering (CBF)** to create an adaptive and personalized digital learning experience. The Agile process enabled continuous improvement through a user-centered feedback loop, ensuring both high functionality and cultural authenticity. Meanwhile, the CBF algorithm successfully personalized content delivery by analyzing semantic feature similarities between historical items. Empirical results from the **User Acceptance Testing (UAT)** with 30 respondents confirmed strong system performance across all evaluation dimensions: Functionality (91%), Usability (90%), Recommendation Accuracy (88%), and User Satisfaction (**93%**). These findings affirm that the synergy between Agile and CBF offers a robust methodological and technical foundation that transforms passive cultural exploration into a dynamic and immersive experience

Contribution, Limitations, and Future Directions (Contribution, Limitation, Future Work)

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Theoretically, this research contributes by establishing a conceptual model where Agile serves as the foundation for responsive cultural system development, while CBF operationalizes personalization through intelligent content mapping. **Practically**, the study provides a scalable framework for cultural organizations, proving that effective personalization is achievable with **limited, semantically curated datasets**, thereby overcoming resource constraints common in heritage informatics. **Nevertheless, the study acknowledges limitations** such as the relatively **small dataset size**, narrow language scope, and short-term evaluation period. Accordingly, **future research directions** should focus on expanding the scope to **hybrid recommendation systems** (to address over-specialization), incorporating multilingual cultural datasets, and conducting longitudinal studies to measure long-term user engagement and knowledge retention.

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