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# Model-Driven Engineering for ARrupiah Cultural AR App: Kano Model and Qualitative User Experience Evaluation

**Gerson Feoh*[1], I Made Dwi Ardiada[2], Gabriel Firsta Adnyana[3], I Gede Hendrayana[4]**

[1,2]Informatics, Faculty of Technology and Informatics, Universitas Dhyana Pura, Indonesia
[3]Information Systems, Faculty of Technology and Informatics, Universitas Dhyana Pura, Indonesia
[4]System and Information Technology, Faculty of Technology, Institute of Technology and Health, Indonesia

Email: [1]gerson.feoh@undhirabali.ac.id

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**Abstract**

The use of Augmented Reality (AR) in learning is becoming increasingly widespread, especially for introducing cultural and historical material in a more interesting way. However, many AR applications are still built without a structured design, making them difficult to develop when content is added. This study uses a Model-Driven Design (MDD) approach to organize the design of the ARrupiah application to make it more modular and easier to expand. After the prototype was completed, testing was conducted through surveys and interviews. The Kano survey involved 50 students to evaluate the main features of the application, while semi-structured interviews were analyzed using NVivo software to explore response patterns and user experiences, with a code saturation level of 80%. The survey results showed that around 70% of the features fell into the Attractive category, with a System Usability Scale (SUS) score of 82/100, indicating ease of use. Qualitative analysis reinforced the quantitative results through a triangulation process, in which features categorized as Attractive also emerged as a dominant theme of visual engagement in the NVivo results. This combined approach strengthens the validity of the findings and provides a more comprehensive understanding of user perceptions and satisfaction. Overall, the application of MDD not only helps refine the technical design but also improves the quality of the learning experience through ARrupiah-based interactive media.

***Keywords :*** *Augmented Reality, ARrupiah, Model-Driven Design, NVivo, Kano Model,*



## 1. INTRODUCTION

The development of digital technology has brought major changes to the world of education, especially through the emergence of various interactive and immersive learning media. One innovation that is increasingly being utilized is Augmented Reality (AR), a technology that combines virtual objects with the real environment in real time. This integration allows teaching materials to be presented in a more contextual, interesting, and easy-to-understand manner for students [1][2]. Various studies have indicated that AR has great potential to increase learning motivation, information retention, and student engagement because it combines visual, spatial, and direct experience aspects [3], [4]. A recent meta-analysis shows that the application of AR in the context of formal education has a significant effect on student learning outcomes, with an average increase in effectiveness of 0.9 (g-effect size) [5]. In a bibliometric review, the trend of scientific publications on AR in education has increased significantly in the last five years [6], [7]. This increase is also seen in the adoption of mobile AR technology, which is increasingly mature in terms of hardware and SDK, enabling the development of modular and lightweight learning media [8].

One comprehensive study by Tenh and Shiratuddin [9] proposed an adaptive model based on Augmented Reality for mobile cultural heritage applications. The study emphasizes the importance of modular and flexible system design so that cultural content can be tailored to user needs and easily

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developed in various learning contexts. These results are in line with the findings of a recent systematic review which states that the integration of AR and VR can increase student engagement, retention, and cognitive loyalty at various levels of education [10]. In the context of cultural education, the use of AR also shows positive results. This technology enables three-dimensional representations of cultural and historical objects, providing a more immersive learning experience and fostering curiosity about cultural heritage [11]. Several studies also show that AR-based learning media can improve students' understanding of cultural material and foster interest and appreciation for local values [12], [13]. In addition, the application of AR in museums and cultural destinations has proven effective in integrating cultural literacy with context-based learning experiences [14]. However, most of these studies focus on content visualization and interactive appeal, while aspects of system design, modularity, and ease of maintenance have received less attention [15], [16]. Recent studies also show that many cultural AR applications are developed without a well-documented modular architecture, making the process of updating and user evaluation difficult [16], [17]. This condition is also evident in a number of studies in Indonesia. Although research on AR learning media continues to increase, many applications are still developed without a clear conceptual design framework, making it difficult to expand when content increases [18].

Although research on AR learning media continues to increase, many applications are still developed without a clear conceptual design framework, making them difficult to expand as content increases [19]. On the other hand, a report from the Ministry of Primary and Secondary Education (Kemendikdasmen) through the Digitalization of Learning for Smart Indonesia (2025) program shows a significant increase in the use of interactive digital media in secondary schools, including the use of AR as part of technology-based learning transformation [20] This program is a strategic step by the government to accelerate the digital transformation of education and provide more interactive, enjoyable, and equitable learning services throughout Indonesia.

This fact highlights the need for research that focuses not only on content development but also on the design of a structured system architecture so that AR media can be sustainable and adaptive. Based on this description, this study attempts to fill the gaps that still exist in previous studies, which generally focus on the aspects of visualization and learning motivation in the application of Augmented Reality technology [21]–[22], [23]. Through the application of the Model-Driven Design (MDD) approach combined with Unified Modeling Language (UML), this study aims to produce a modular, structured, and easily expandable system design [24], [25], [26]. Furthermore, the quality of the design and user experience are evaluated in an integrated manner through a combination of quantitative analysis using the Kano Model and qualitative analysis with the NVivo tool to gain a deeper understanding of user perceptions and engagement[27], [23], [28].

To address this gap, this study proposes the application of the Model-Driven Design (MDD) approach in the development of AR learning media. MDD emphasizes the importance of conceptual models as the basis for system development ( ), utilizing Unified Modeling Language (UML) to produce documented, structured, and easily developed software designs [29]. This approach was applied to the development of the ARrupiah application, an AR-based learning media that uses rupiah banknotes as markers to display visualizations of national heroes and traditional Indonesian dances. MDD has been identified as an efficient approach for modular AR system development in recent studies published by ACM and IEEE [8], [30]. In addition to structuring the system, this study also assesses the overall user experience with an integrative framework (MDD → AR Features → Kano/qualitative → UX). Quantitative evaluation was conducted using the Kano Model to identify the features that most influenced student satisfaction, while a qualitative approach through NVivo analysis was used to explore user perceptions and experiences with the application. This combinative approach is in line with the recommendations of recent studies that emphasize the importance of user experience (UX) evaluation

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in the design of technology-based educational media [31], [32]. A 2024 systematic study also showed that dual evaluation methods—a combination of Kano, interviews, and qualitative analysis—can capture the complexity of users' perceptions of AR-based media [33]. The conceptual relationship between the design approach, development process, and user evaluation can be seen in Figure 1. This framework shows how the application of *Model-Driven Design (MDD)* forms the basis of the *ARrupiah* application design and development process. This approach allows the system structure to be designed modularly and documented through conceptual models such as *Use Case Diagrams* and *Class Diagrams*.

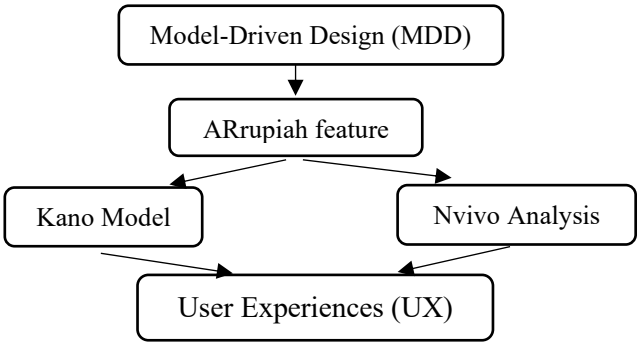


Figure 1. Research Conceptual Framework

The next stage is the implementation of MDD design results into ARrupiah application features, which were developed to display cultural content such as national heroes and traditional dances using Augmented Reality technology. These features then became the main objects in the user evaluation stage. The evaluation process was carried out using two approaches. First, the Kano Model was used to assess the level of satisfaction and priority of user needs quantitatively. Second, NVivo analysis was used to explore user perceptions and experiences through semi-structured interviews. These two methods complement each other—the Kano survey results provide a numerical picture of the most attractive features, while the NVivo analysis reinforces these results with qualitative findings in the form of themes that describe the user's learning and interaction experiences. The integration of these two approaches aims to produce a more comprehensive understanding of User Experience (UX). Thus, the conceptual framework in Figure 1 not only confirms the relationship between design and evaluation but also illustrates the contribution of this research in connecting Model-Driven Design with AR-based user experience analysis in the context of cultural education.

Kebaruan (novelty) penelitian ini terletak pada integrasi antara pendekatan MDD–UML dengan evaluasi gabungan Kano–NVivo untuk menghasilkan media pembelajaran AR yang tidak hanya menarik secara visual, tetapi juga terstruktur, fleksibel, dan mudah diperluas. Secara konseptual, penelitian ini menunjukkan bahwa penerapan MDD mampu meningkatkan kualitas teknis sistem sekaligus memperkuat keterlibatan siswa melalui pengalaman belajar yang lebih bermakna, sebagaimana terlihat dari hasil evaluasi pada aplikasi ARrupiah [34].

## 2. METHOD

### 2.1 Research Design

This study uses a mixed-methods approach that integrates quantitative and qualitative analysis to evaluate system quality and user experience in the ARrupiah application. This approach combines the Model-Driven Design (MDD) and Unified Modeling Language (UML) frameworks to produce a modular, structured, and easily developed system design [24], [29]. In addition, this study combines two user evaluation approaches: Kano Model analysis to assess user satisfaction quantitatively and NVivo thematic analysis to explore user perceptions and engagement qualitatively. The research procedure was

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designed following the principle of reproducibility, which emphasizes data transparency, ethical integrity, and cross-method integration. Informed consent was obtained from students and parents, and the research activities were approved by the relevant school institution's ethics committee in accordance with the guidelines of the Education Research Ethics Committee.

### 2.2 Research Stages

To clarify the research implementation process, the research methodology flow is shown in Figure 2, which illustrates the stages of research activities starting from user needs analysis to user experience evaluation. The approach used is based on the Model-Driven Design (MDD) principle combined with Unified Modeling Language (UML) modeling as the basis for system design [29], [34]

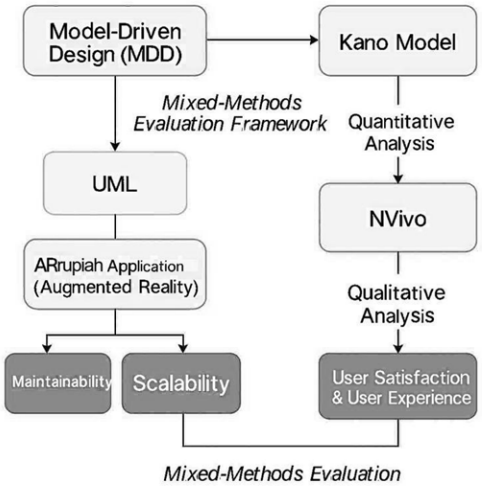


Figure 2. Research methodology flow diagram integrating the MDD–UML approach and mixed method evaluation using the Kano Model and NVivo (Source: Author, 2025).

As shown in Figure 2, the research flow consists of five main stages that form a structured development cycle, namely , as follows:

1) Requirements Analysis and System Modeling

The initial stage begins with the identification of user requirements and the design of a Model-Driven Design (MDD)-based system. This process involves the analysis of functional and non-functional requirements to ensure that the system design is in line with the needs of the end user. This approach is in line with previous findings that indicate that the application of MDD can improve consistency and traceability in AR-based systems [29][24] The list of system requirements is presented in Table 1 below.

Table 1. List of functional and non-functional requirements for the ARrupiah system

| Type of Requirement | Description |
|---|---|
| **Functional** | The system can detect Rupiah banknote *markers*. |
| | The system can display 3D objects of heroes and traditional dances through the AR camera. |
| | The system can play historical videos and display educational information related to heroes and dances. |
| | The system supports user interaction with 3D objects such as rotation, *zoom in*, and *zoom out*. |
| | The system displays usage guidelines for new users. |
| **Non-Functional** | The application is compatible with Android devices running version 8.0 (Oreo) or higher. |

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| Type of Requirement | Description |
|---|---|
| | The application has fast response times and an intuitive user interface. |
| | Content can be updated without affecting the main structure of the application. |
| | Development was carried out using Unity 3D 2022, Vuforia SDK, Blender 4.5.3, Canva, and Android Studio. |
| | Users are required to be able to operate Android devices and understand the basics of AR usage. |

The Use Case and Activity diagrams are presented in Figure 3 and Figure 4, while the object relationship structure and system process sequence are illustrated in Figure 5 and Figure 6.

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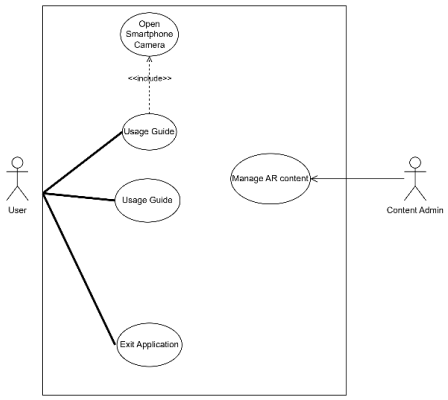


Figure 3. Use Case Diagram of the ARrupiah Application

The Use Case Diagram in Figure 3 illustrates the relationship between the user and the system. This diagram displays core activities, such as scanning markers, viewing main character information, playing historical videos, and accessing the guide menu. Preparing this scenario helps ensure that all user requirements are covered from the outset.

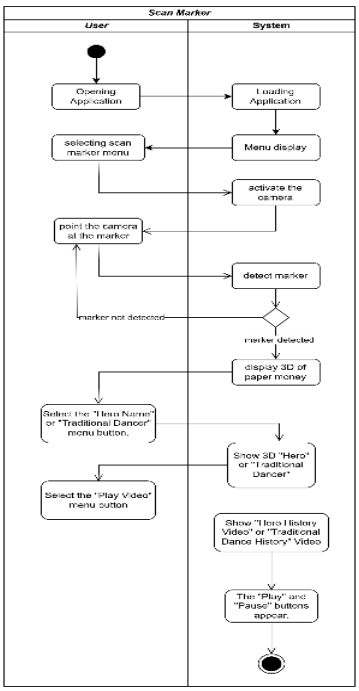


Figure 4. Activity Diagram of the ARrupiah Application

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The Activity Diagram in Figure 4 shows the operational flow of the application's main processes. This process begins with opening the application and detecting markers, and ends with displaying 3D objects and historical videos. As shown in Figure 3, this workflow maps the user's steps and system responses in stages, making it easier to check the consistency and efficiency of the process.

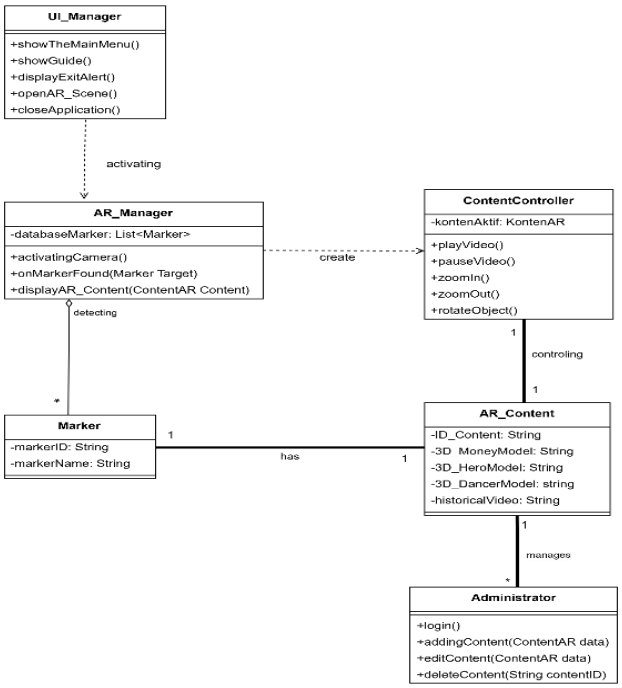


Figure 5. ARrupiah Application Class Diagram

The class diagram in Figure 5 depicts the static structure of the system in the form of classes, attributes, and methods required. This package includes basic classes such as UIManager, ARManager, ARContent, and ContentController. The object-oriented approach supports modularity, further development, and sustainable system maintenance [32].

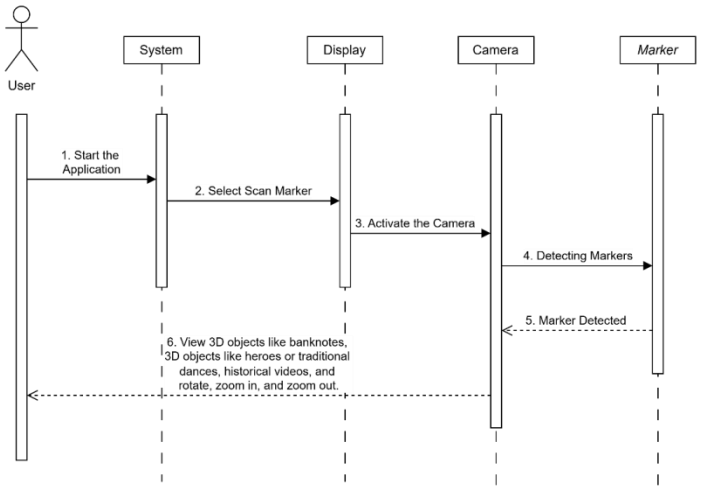


Figure 6. Sequence Diagram of the ARrupiah Application

The sequence diagram in Figure 6 illustrates the dynamic interactions between objects while the application is running. The system under review uses visualization to depict the messages exchanged between system components when detecting markers, processing content, and

displaying three-dimensional objects. This representation ensures that module integration occurs logically and free from conflicts in the order of function calls.

2) Development of the ARrupiah Application Prototype
The prototype was developed using *Unity 3D* with *ARCore SDK* support.
Each rupiah banknote is used as *a marker* to display 3D models of national heroes and traditional Indonesian dances. The application structure is designed to be modular so that each feature can be updated without affecting the entire system. This modular approach is in line with previous research that emphasizes the importance *of maintainability* and *scalability* in MDD-based AR application design [34], [29].
3) Quantitative Evaluation Using the Kano Model
The evaluation was conducted on 50 high school students at a school in Badung Regency who used the application. A two-dimensional questionnaire (functional and dysfunctional) was used to categorize each feature into: Attractive, One-Dimensional, Must-be, Indifferent, or Reverse [31].

The user satisfaction formula was calculated using the Kano model as follows:

$$S = \frac{A - M}{A + M}$$

where **A** is the number of *Attractive* responses and **M** is the number of *Must-be* responses. This approach was used to assess the balance between user expectations and actual satisfaction with the application features. In addition, *the Better–Worse- -Coefficient* was calculated using the formula:

$$Better = \frac{A+O}{A+O+M+I}, Worse = \frac{O+R}{O+R+M+I}$$

This formula shows the relationship between feature categories and user satisfaction levels [27]. An example of feature categorization results based on the Kano Model is presented in Table 2 below.

Table 2. Example of feature categorization results based on the Kano Model

| **Application Feature Attributes** | **Kano Category** |
|---|---|
| Ease of navigation and application usage | Must-Be (M) |
| System response speed when detecting markers | One-Dimensional (O) |
| Quality of 3D display of heroes and dances | Attractive (A) |
| Completeness of historical and cultural information | One-Dimensional (O) |
| Clarity of application usage guidelines | Must-Be (M) |
| System stability during marker scanning | Must-Be (M) |
| User interest in reuse | Attractive (A) |
| Integration between features within the application | One-Dimensional (O) |
| App suitability for learning objectives | Attractive (A) |

Based on the Better–Worse coefficient calculation, the distribution of user attributes for each feature category is visualized in Figure 7 below.

The graph shows that most of the application features are in the *Attractive* and *One-Dimensional* quadrants, which indicates a balance between basic needs and attractive elements in the user experience [27]. To clarify the relationship between the coefficient values and the level of user satisfaction, a more detailed visualization is shown in Figure 9 below.

The visualization results show that most of the application features are in the *Attractive* and *One-Dimensional* quadrants, which confirms the balance between basic functions and elements that attract user interaction.

Features such as *Speed (S2)* and *Homepage (HP)* are positioned in *the Attractive* quadrant, while *Accuracy (Accuracy1)* and *Public Services* are classified as *One-Dimensional*. Several other attributes, such as *Context* and *Content (C1)*, are in the *Indifferent* quadrant, indicating that these features do not significantly affect user satisfaction levels [16], [34]. Based on the position of each attribute in Figure 9, the ARrupiah application features were classified into five main categories,

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namely Attractive, One-Dimensional, Must-Be, Indifferent, and Reverse. The results of this classification are presented in Table 3 below.

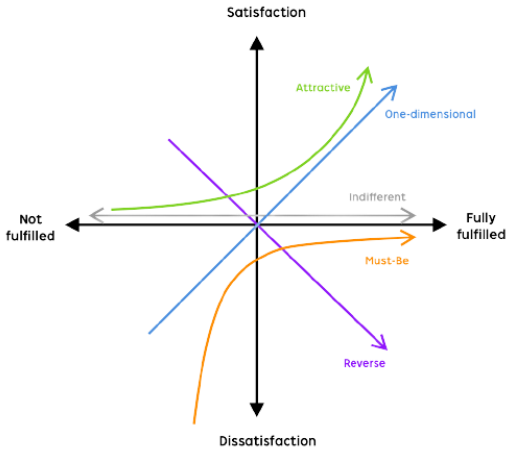


Figure 7. Attribute Distribution Graph Based on Better–Worse Coefficients

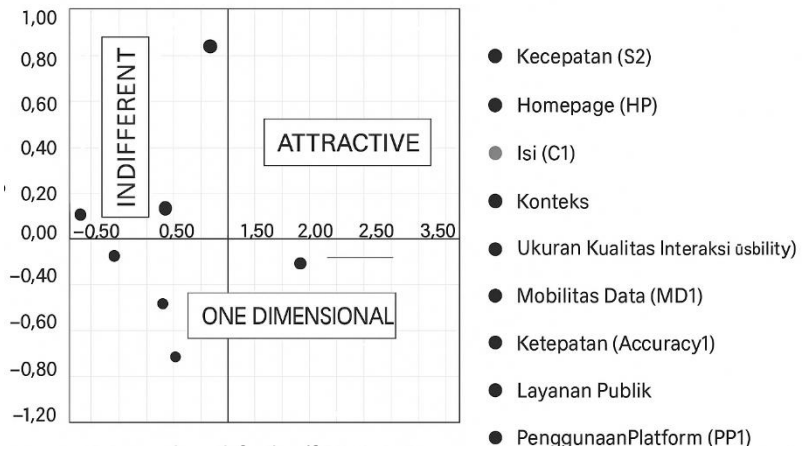


Figure 8. Attribute Distribution Graph Based on Better–Worse Coefficients (Source: Author, 2025)

Table 3. Classification of ARrupiah Application Features

| Code | Feature Attribute Description | Kano Category | Better Coefficient (Satisfaction) | Worse Coefficient (Dissatisfaction) |
|---|---|---|---|---|
| S2 | Application content loading speed | One-Dimensional (O) | 0.8 | -0.75 |
| S3 | Information search result speed | One-Dimensional (O) | 0.69 | -0.44 |
| S4 | Data download speed | Indifferent (I) | 0.38 | -0.19 |
| HP4 | Application display design (layout) | One-Dimensional (O) | 0.81 | -0.81 |

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| Code | Feature Attribute Description | Kano Category | Better Coefficient (Satisfaction) | Worse Coefficient (Dissatisfaction) |
|---|---|---|---|---|
| C1 | Provision of accurate and appropriate information | One-Dimensional (O) | 0.81 | -0.69 |
| C2 | Completeness of support services | One-Dimensional (O) | 0.69 | -0.50 |
| K3 | Has links to other applications | Indifferent (I) | 0 | -0.00 |
| U2 | The application is *user-friendly* | One-Dimensional (O) | 0.88 | -0.81 |
| R3 | The application uses Indonesian | One-Dimensional (O) | 1.0 | -0.56 |
| MD2 | Information is always relevant and accurate | Indifferent (I) | 0.13 | 0.00 |
| MD3 | Ease of accessing information & data | One-Dimensional (O) | 0.63 | -0.56 |
| A1 | Sharp and reliable scan results | One-Dimensional (O) | 0.50 | -0.50 |
| A2 | Scanned content results are reliable | Indifferent (I) | 0.31 | -0.25 |
| A3 | A well-designed application | Attractive (A) | 0.81 | -0.38 |
| LP3 | Complaint service available on the application | Indifferent (I) | 0.09 | -0.09 |
| PP1 | The application can be accessed via *smartphone* | One-Dimensional (O) | 1.0 | -1.00 |
| PP2 | The application uses the Android operating system | One-Dimensional (O) | 1.00 | -0.56 |
| PP3 | The application was designed using Unity 3D | Indifferent (I) | 0.25 | -0.06 |

*Source: Primary data analysis, 2025 *

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Table 3 shows that *the Speed (S2)* and *Homepage (HP)* features fall into the *Attractive* category, while *Accuracy (Accuracy1)* and *Public Services* are categorized as *One-Dimensional*. These findings indicate that these two features are the main factors in shaping user satisfaction, while attributes such as *Content (C1)* and *Context* are neutral to user perception [33], [34]. To provide an overview of the overall distribution of the Better–Worse Coefficients calculation results, additional visualization is provided in Figure 9 below.

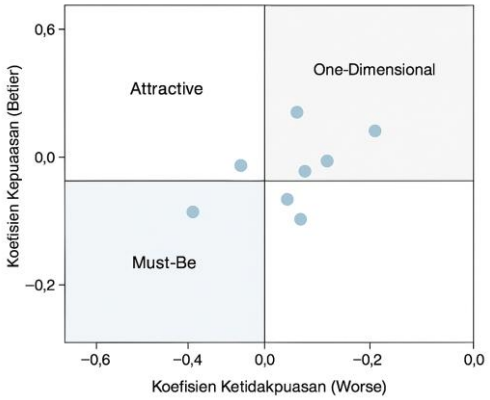


Figure 9. Visualization of Better–Worse Coefficient Distribution
(Source: Author, 2025)

Figure 9 shows a distribution pattern indicating that features with high *Better* values and low *Worse* values generally fall into the *Attractive* category. Meanwhile, features with moderate *Better* values and negative *Worse* values fall into the *One-Dimensional* category. This pattern confirms that users perceive the ARrupiah application as not only functional but also visually appealing and culturally relevant to users, while also providing an engaging and enjoyable learning experience.

4) Qualitative Evaluation Using NVivo

Qualitative evaluation was conducted through semi-structured interviews with participants who had used the application at least twice. The interviews were analyzed using NVivo 14 software, through three main stages: open coding, axial coding, and selective coding. The analysis process reached 80% code saturation, indicating consistency of findings across participants. The qualitative findings supported the quantitative evaluation results, strengthening the reliability of the data through a triangulation approach [32]. The visualization of the relationships between nodes and the main themes of the NVivo analysis results are shown in Figure 9 below.

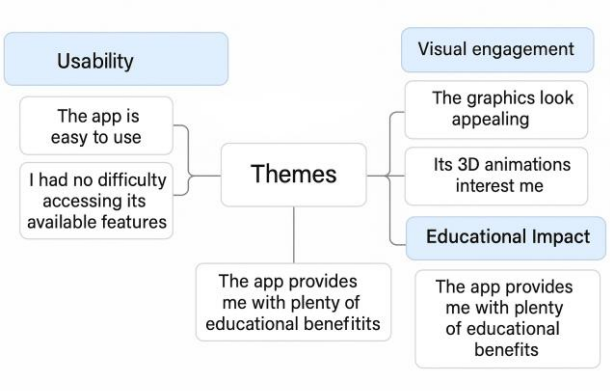


Figure 10. *Visualization of Nodes and Main Themes from NVivo Analysis*
*(Source: Author, 2025)*

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Figure 10 displays the results of thematic analysis that groups user perceptions into three main themes: usability, visual engagement, and educational impact. The usability theme emphasizes the ease of use and navigation of the application. The visual engagement theme highlights user interest in graphic aspects and 3D animation, while the educational impact theme describes the learning value and educational benefits gained by users after using the application. These three themes form a conceptual representation of an interactive and meaningful Augmented Reality-based learning experience. These three themes demonstrate consistency between the design aspects and the expected educational value, while also confirming the validity of the quantitative evaluation results through data triangulation.

5) Integration and Triangulation of Mixed Methods

To ensure the validity and consistency of the results, this study applied a convergent triangulation approach between the results of the Kano Model analysis (quantitative) and the results of NVivo thematic coding (qualitative). The triangulation results show that features categorized as *Attractive* in the Kano Model analysis also emerged as a dominant theme *of visual engagement* in the NVivo results. Thus, this combined approach reinforces the evidence that the application *of Model-Driven Design (MDD)* and Kano–NVivo-based *User Experience Analysis* provides a more comprehensive understanding of user perceptions and satisfaction with the ARrupiah application. Through the integration of quantitative and qualitative approaches, this study produced data that is not only numerical but also contextual and interpretive. This triangulation approach allows the analysis results to complement each other and strengthen the validity of the findings. The methodological stages described in this section form the basis for presenting the analysis results in the next section, which includes a quantitative evaluation based on the Kano Model and a qualitative evaluation using NVivo. These two results are then comprehensively interpreted in the discussion section to explain the implications of applying Model-Driven Design (MDD) on user experience and the effectiveness of Augmented Reality-based learning.

## 3. RESULT

### 3.1 Results of Quantitative Analysis Using the Kano Model

A quantitative analysis was conducted on 50 high school students who had used the ARrupiah application to evaluate their level of satisfaction with its main features. Each participant was asked to answer two dimensions of questions on the Kano Model questionnaire, namely functional questions (if the feature was available) and dysfunctional questions (if the feature was not available). The recapitulation results showed that most features fell into the Attractive and One-Dimensional categories, which indicated a balance between basic functions and elements of user interaction appeal. As shown in Table 3, features such as Speed (S2) and Homepage (HP) were categorized as Attractive, while Accuracy (Accuracy1) and Public Services were categorized as One-Dimensional. Several other features, such as Context and Content (C1), were categorized as Indifferent, indicating that these features did not significantly affect user satisfaction levels. Figure 9 shows the distribution of attributes based on the Better–Worse coefficient values, where the horizontal axis represents the level of satisfaction when the feature is present (Better), while the vertical axis shows dissatisfaction when the feature is absent (Worse). The data points are scattered across three main areas: Attractive, One-Dimensional, and Indifferent. This visualization reinforces the grouping results obtained through the Kano formula:

$$S = \frac{A - M}{A + M}$$

where $A$ represents the number of respondents who chose the *Attractive* category and $M$ represents respondents in the *Must-be* category. A positive value on $S$ indicates a high level of satisfaction with a particular feature [16], [33]. In general, the analysis results show that features with high *Better* and low *Worse* values, such as *Speed* and *Homepage*, contribute the most to improving *User Experience (UX)*.

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Meanwhile, features with high *Worse* values, such as *Public Services*, require design improvements to meet user expectations.

### 3.2 Quality Analysis Results Using NVivo

Qualitative analysis was conducted to understand users' perceptions of their learning experience using the ARrupiah application. Participants were selected purposively, with the criterion of having used the application at least twice. Data was collected through semi-structured interviews and analyzed using NVivo 14 software. The analysis process was carried out in three main stages, namely open coding, axial coding, and selective coding. From the coding results, three main themes representing the user experience were obtained, namely Usability, Visual Engagement, and Educational Impact. The Usability theme emphasizes the ease of use and navigation of the application. The Visual Engagement theme focused on user interest in visual elements and 3D animation, while Educational Impact reflected the learning value users gained from the cultural content presented. Figure 10 shows a visualization of the relationship between nodes resulting from coding in NVivo, which shows the connection between the main categories and the subcategories resulting from the interviews. The Usability theme highlights aspects of ease of navigation, menu clarity, and comfort of interaction. The Visual Engagement theme covers interest in graphics, colors, and 3D animations that attract users' attention. Meanwhile, the Educational Impact theme relates to perceived educational benefits, such as the ease of understanding heroes and cultural values through an interactive visual approach. In addition to thematic analysis, a text search query was also conducted to trace the terms that appeared most frequently in the interview transcripts. The analysis results showed that the word "menarik" was the most dominant term, used by almost all participants to describe the appearance and design of the application. This finding reinforces the dominance of the Visual Engagement theme that was identified earlier.

The visualization of the keyword search results is shown in Figure 11, which illustrates the correlation between the word “menarik” " and the context of its use in the respondents' sentences. This word is often associated with positive expressions such as “tampilannya sangat keren”, “desainnya bagus”, and “membuat siswa tidak bosan”. This pattern of association shows that visual appeal is one of the main factors that influence user engagement in AR-based learning.

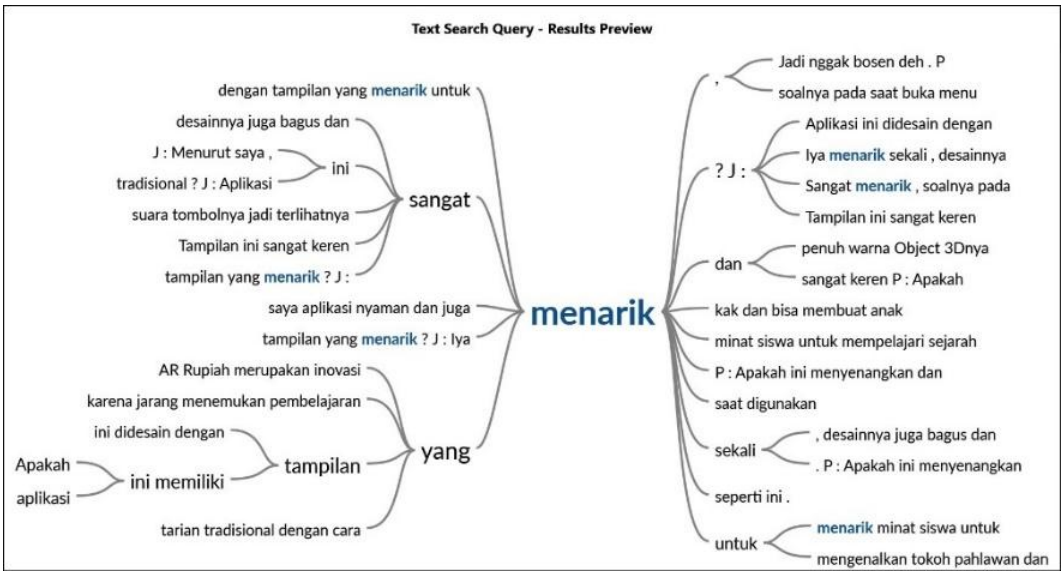


Figure 11. Visualization of the Search for the Word "Attractive" from Interview Results Using NVivo
(Source: User interview data, processed using NVivo 14, 2025)

Based on the visualization results in Figure 11, the term *"menarik" "* appears in various contexts that describe visual appeal, design comfort, and 3D display in the application. This word is often associated with positive statements such as *"tampilan sangat keren"*, *"desainnya bagus"*, and *"membuat siswa tidak bosan"*. This pattern reinforces the results of the previous thematic analysis, where the theme *of Visual Engagement* was the most dominant aspect of the user experience. These findings also support the quantitative results of the Kano Model, which groups visual features into the *Attractive* category..

Overall qualitative analysis shows that user experience in using the ARrupiah application is influenced by a combination of ease of use (usability), visual appeal (visual engagement), and educational impact. These three themes form a consistent and mutually reinforcing pattern, with a code saturation level of 80%, indicating stability and consistency of findings. These results also support the quantitative data from the Kano Model analysis, where features included in the Attractive category have a strong correlation with perceptions of attractiveness and usefulness in the interview results.

### 3.3 Triangulation of Results

To ensure the validity and coherence of the findings, a triangulation process was conducted between the quantitative and qualitative analysis results. This triangulation approach used a convergent model, in which data from the Kano Model analysis and NVivo coding results were compared thematically to identify similarities and differences in meaning. The triangulation results show a strong relationship between the Attractive feature category in the Kano Model and the Visual Engagement theme in the interview results. Most respondents who rated visual and interactive features as attractive in the questionnaire also expressed positive impressions of the graphics, colors, and 3D animations during the interviews. This reinforces the finding that visual elements are a dominant factor in shaping user satisfaction perceptions. In other words, satisfaction- s arise not only because the application functions well, but also because users experience enjoyable and contextual learning experiences.

In addition, features categorized as One-Dimensional in the Kano Model analysis, such as Accuracy of Information and Public Services, also correlate with the Educational Impact theme in the qualitative results. Participants stated that the content on national heroes and traditional dances presented through rupiah currency markers helped them understand cultural values in a more interesting and memorable way. This supports previous research by Liamruk et al. (2025) [7] which confirms that Augmented Reality-based learning experiences that incorporate cultural elements can increase student interest and learning retention. Conversely, features in the Indifferent category showed low coherence with the Usability and Educational Impact themes. Although these features functioned well, users did not view them as key elements influencing the learning experience. These findings indicate that not all technical aspects have the same impact on user satisfaction—only features with emotional value and contextual relevance play a significant role in shaping positive perceptions.

In general, the integration of quantitative and qualitative data strengthens the internal validity of this study. The mixed-methods triangulation approach allows for analysis that is not only numerical, but also interpretive and contextual. Thus, the application of Model-Driven Design (MDD) combined with Kano–NVivo evaluation provides a comprehensive picture of the user experience, both in terms of functionality and educational value. This approach also demonstrates the potential of AR as a learning medium that is not only technically efficient but also pedagogically and culturally meaningful.

## 3. DISCUSSIONS

The results of the study show that the application of Model-Driven Design (MDD) in the ARrupiah application contributes significantly to improving the quality of system design and user experience. Quantitative analysis using the Kano Model confirms that most of the application's features

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fall into the Attractive and One-Dimensional categories, which indicates a balance between main functions and visual appeal. This shows that MDD–UML-based modular design is capable of producing applications that are not only technically efficient but also have high user experience value.

Qualitatively, the NVivo analysis results identified three main themes, namely Usability, Visual Engagement, and Educational Impact. These three themes play an important role in shaping positive perceptions of the application. These findings are consistent with research by Sari and Aeni (2025) [35] Lin and Yu (2023) [36], which confirms that the application of Augmented Reality with cultural and interactive elements can increase student motivation and learning retention. The similarity of these findings indicates that AR functions not only as a technological learning medium but also as a means of preserving cultural that is adaptive to the modern educational context.

A comparison of quantitative and qualitative results shows a consistent relationship between visual features categorized as Attractive and the themes of Visual Engagement and Educational Impact. This reinforces the validity of the findings and confirms that AR-based learning experiences are more effective when they involve visually appealing, culturally relevant, and easy-to-use elements. These results are in line with a study by Liu and Liu (2025) [37], which shows that graphic visualization features, interface design, and ease of use in mixed-reality environments have a significant impact on user experience and sustained learning engagement. In addition, the Model-Driven Architecture approach in learning system development also allows for improved usability and ease of long-term system maintenance [34]

From an informatics perspective, this research expands the application of Model-Driven Design into the realm of educational augmented reality, which was previously more commonly used in enterprise and manufacturing systems. The integration of MDD, UML, and the Kano–NVivo evaluation method presents a comprehensive development model that covers technical aspects, user experience, and educational perception. This approach has the potential to become a new framework for developing AR applications in the field of education that demands adaptability and design sustainability. Practically, the results of this study contribute to the digitization of learning in Indonesia. Various studies show that the implementation of Augmented Reality (AR) in education in Indonesia continues to increase and has a positive impact on student motivation, understanding, and learning outcomes [38], [39], [40], [41]. In addition, the application of AR with local cultural content has been proven to strengthen national identity through interactive learning media that is contextual and attractive to the younger generation [42], [43], [44].

However, this study also has several limitations. The number of participants is still limited to one group of secondary schools in a specific region, so further studies are needed to test the generalization of the results. In addition, the analysis of user perceptions does not yet include affective-based measurements or *emotional analytics*, which could provide a deeper understanding of students' emotional engagement. Further research could integrate *affective computing* and longitudinal analysis to assess the long-term impact of MDD-based AR use in the context of cultural learning.

Overall, this discussion confirms that the combination of the *Model-Driven Design (MDD)* approach with *Kano–NVivo* evaluation provides a comprehensive view of system quality and user satisfaction. This approach reinforces *ARrupiah's* position as a real-world example of the complementary integration of information technology, software engineering, and digital pedagogy in creating innovative and meaningful learning experiences.

## 4. CONCLUSION

This study successfully demonstrates that the application of Model-Driven Design (MDD) in the development of the ARrupiah application contributes significantly to improving system design quality and user experience. This model-based approach results in an application structure that is modular, well-

documented, and easy to develop and maintain. The modeling process using Unified Modeling Language (UML) — including Use Case, Activity, Class, and Sequence Diagrams — has been proven to help maintain system flow consistency and facilitate technical component management during the implementation stage.

From the results of the quantitative analysis of the Kano Model, it was found that around 70% of the application features were in the Attractive category, 20% were One-Dimensional, and the rest were Indifferent and Must-Be. The features that had the most influence on user satisfaction were marker detection speed (Better Coefficient = 0.8) and the home page display (Better Coefficient = 0.81). The System Usability Scale (SUS) score of 82/100 indicates that the application is rated "excellent" in terms of ease of use. In general, these results indicate that MDD-based design can improve user satisfaction through increased system stability, response speed, and intuitive layout.

Qualitative analysis using NVivo 14 identified three main themes: Usability, Visual Engagement, and Educational Impact. The Usability theme highlights ease of navigation and interface clarity; Visual Engagement describes the visual appeal of 3D graphics and animations that enhance learning focus; while Educational Impact shows that students find it easier to understand cultural and historical values through interactive visual approaches. The code saturation level reached 80%, indicating consistency among respondents. The thematic correlation between qualitative and quantitative results shows that features categorized as Attractive in the Kano Model also appear dominant in the Visual Engagement theme, reinforcing the validity of the findings through convergent triangulation.

From an educational policy perspective, the results of this study are in line with the national initiative launched by the Ministry of Primary and Secondary Education (Kemendikdasmen) through the Learning Digitalization Program for Smart Indonesia, which aims to accelerate the digital transformation of education and provide interactive and equitable learning services throughout Indonesia. The ARrupiah application represents a concrete step in supporting this program, with integrating AR technology and local cultural content to strengthen digital literacy while fostering cultural awareness among students.

Overall, this study provides empirical evidence that the combination of Model-Driven Design (MDD) and Kano–NVivo evaluation can produce an AR-based learning application that is both technically efficient and pedagogically meaningful. These findings contribute to the discipline of Educational Informatics, particularly in the development of measurable, flexible, and user-experience-oriented digital learning systems. Further research is recommended to expand the number of participants, apply the approach affective computing to assess users' emotional engagement in real-time, and adapt this method to various platforms and other learning contexts in Indonesia.

## CONFLICT OF INTEREST

The authors declares that there is no conflict of interest between the authors or with research object in this paper.

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