

Application of Visual Data Mining for Visualization of UKBI Achievement Data

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ABSTRACT

The current visualization of Adaptive Indonesian Language Proficiency Test (UKBI Adaptif) results in Jambi Province is suboptimal, often relying on static, basic charts, which hinders transparency and the effective formulation of evidence-based language policies. This research aims to address this critical gap by developing an interactive, data-driven system to analyze the language proficiency profile of UKBI participants in Jambi from 2021 to 2024. The research objective is to accurately map regional competence, identify hidden patterns, and provide actionable intelligence to the Jambi Language Center. The study adopts the Visual Data Mining (VDM) methodology, integrating interactive visualization with the K-Means clustering algorithm. This method allowed for the normalization and grouping of over 10,000 participant data points, with the optimal number of clusters determined by the Silhouette Score. The research results successfully established three distinct proficiency clusters, including a "Listening Struggler Group" dominated by non-education professions, exhibiting significantly low scores in the Listening section. Furthermore, geographical analysis revealed a disparity where Jambi City—the region with the highest participation—maintained an average proficiency at the lower boundary of the Intermediate category, while smaller regions like Muaro Jambi showed higher rates of Superior and Exceptional achievement. The conclusion is that the VDM-based interactive dashboard is a validated and effective tool that successfully provides micro-level insights, supporting the strategic allocation of resources and the design of targeted intervention programs to address specific skill weaknesses, such as listening comprehension.

INTRODUCTION

The Urgency of the Indonesian Language and Proficiency Standardization The Indonesian language plays a vital role in the national social, economic, and cultural order, functioning as the primary tool of communication as well as a unifying bridge for ethnic diversity, and serving as a supporting pillar for the advancement of science and the digital economy (Badan Pengembangan dan Pembinaan Bahasa, 2021). Varying levels of individual language proficiency necessitate the existence of a standardized measurement instrument (Tantri, 2018), similar to international tests such as TOEFL, HSK, or JLPT (Nafri Yanti, 2018). In Indonesia, this need is met by the Adaptive Indonesian Language Proficiency Test (Uji Kemahiran Berbahasa Indonesia-UKBI Adaptif), a program developed by the Language Development and Fostering Agency to standardize Indonesian language proficiency levels (UKBI kemdikbud, 2020). The implementation and management of UKBI at the regional level, including Jambi Province, fall under the responsibility of Balai Bahasa of Jambi Province (BBPJ) (Balai Bahasa Provinsi Jambi, 2024).

Identification of Data Visualization Problems and the Need for Solutions Although UKBI is a valid measurement instrument, there are significant constraints regarding the utilization of its data. Based on interview results, the current visualization of UKBI achievement data by the BBPJ is considered suboptimal, generally consisting only of static barcharts and pie charts created using Excel and published on social media. This limitation results in a lack of transparency, complicates in-depth data analysis, and hinders the identification of trends in proficiency improvement or decline at the regional level (Azzam et al., 2020). The complex and diverse condition of the data, which encompasses various regions, timeframes, and proficiency levels, demands an approach capable of transforming data into simple, meaningful, and actionable information (Fernando, 2018).

Proposed Methodological Solution and Research Objectives To address these challenges in visualization and data analysis, this research proposes the application of the Visual Data Mining (VDM) methodology. VDM was selected for its capability to integrate interactive visualization techniques with data mining processes, thereby enabling the efficient and effective exploration of hidden patterns and trends within complex data (Simoff et al., 2018). The VDM approach has proven successful in various case studies involving the analysis of distribution patterns and population trends (Ghivary et al., 2023). Therefore, this research aims to develop a data visualization of UKBI Adaptif participant achievements in Jambi Province using VDM, which is expected to enhance transparency, facilitate analysis, and support more strategic and accurate evidence-based policy decision-making.



LITERATURE REVIEW

This study aims to analyze the Indonesian language proficiency profile in Jambi Province using secondary data from the results of the Adaptive Indonesian Language Proficiency Test (UKBI Adaptif). UKBI Adaptif is a standardized national online measurement tool administered by the Language Development and Fostering Agency. The development of its adaptive model began in 2016 (UKBI kemdikbud, 2016) and was further strengthened by the establishment of official standards (Kepmendikbud No. 70 of 2016). This test assesses five aspects of language proficiency, and the results are grouped into seven predicate ranks, ranging from "Terbatas" (Limited) to "Istimewa" (Exceptional) (UKBI - Uji Kemahiran Berbahasa Indonesia, 2022). Data encompassing the test participants' professions and the score predicates they achieved form the focus of the analysis to identify specific proficiency patterns among population groups. This study attempts to fill the information gap regarding the map of language competence at the regional level, which is essential as a basis for evaluating the effectiveness of language development programs and designing more focused intervention policies in the future.

Visual Data Mining (VDM) is a data analysis methodology that integrates interactive visualization with human cognitive intelligence, allowing users to create meaning through an iterative analytical reasoning process (Simoff et al., 2018). This approach was chosen in this research to optimize the interpretation of UKBI (Indonesian Language Proficiency Test) data, thereby facilitating the efficient identification of language proficiency trends and the mapping of achievement patterns (Yoshua & Apsiswanto, 2023). The VDM framework is applied through three main phases. The Project Planning Phase focuses on project justification, scope definition (from proof-of-concept to production), and the identification of core questions that the visualization needs to answer (Andriansyah, 2022). Subsequently, the Data Preparation Phase ensures data integrity through the crucial stages of selection, transformation, and verification, which includes cleansing and filtering processes to ensure the data is ready for analysis (Aryanti & Setiawan, 2019). Finally, the Data Analysis Phase involves selecting appropriate visualization tools, deep analysis of the patterns emerging in the visualizations, and final verification before the presentation of results to support data-driven decision-making (Andriansyah, 2022). The systematic implementation of VDM provides a strong basis for uncovering the complexity of the UKBI data and filling the information gap at the regional level.

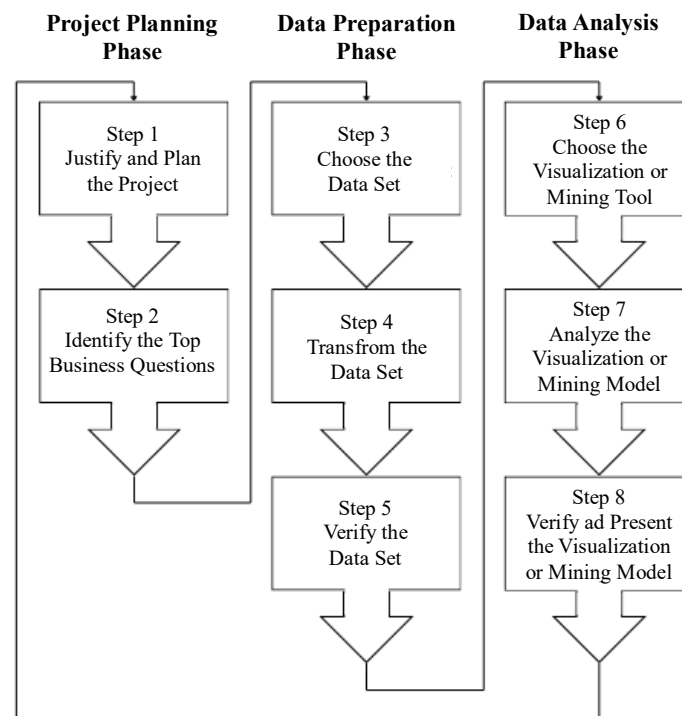


Fig. 1 Visual Data Mining
Sumber: (Yoshua & Apsiswanto, 2023)

Data Mining is defined as an analytical approach for extracting hidden patterns and prospective trends from large-volume data, utilizing machine learning and statistical techniques (Aqsha et al., 2025). This activity is an integral part of the structured Knowledge Discovery in Database (KDD) process, which begins with Data Cleaning and Transformation before proceeding to the core data mining stage, and concluding with the Interpretation and Evaluation of findings (Adiya & Desnelita, 2019). In this study, the focus is placed on the Clustering technique, an unsupervised grouping method that organizes data based on inherent characteristic similarities (Mufid et al., 2023). Specifically, the

K-Means algorithm is utilized, chosen for its efficiency and simplicity in dividing data into defined clusters (Ding et al., 2021). K-Means operates iteratively, starting with the random selection of centroids, followed by distance measurement, and the placement of data into the nearest cluster, repeating until convergence is reached (Fakhriza & Umam, 2021). The application of K-Means aims to uncover hidden grouping patterns of Indonesian language proficiency, providing an analytical basis for the research conclusions.

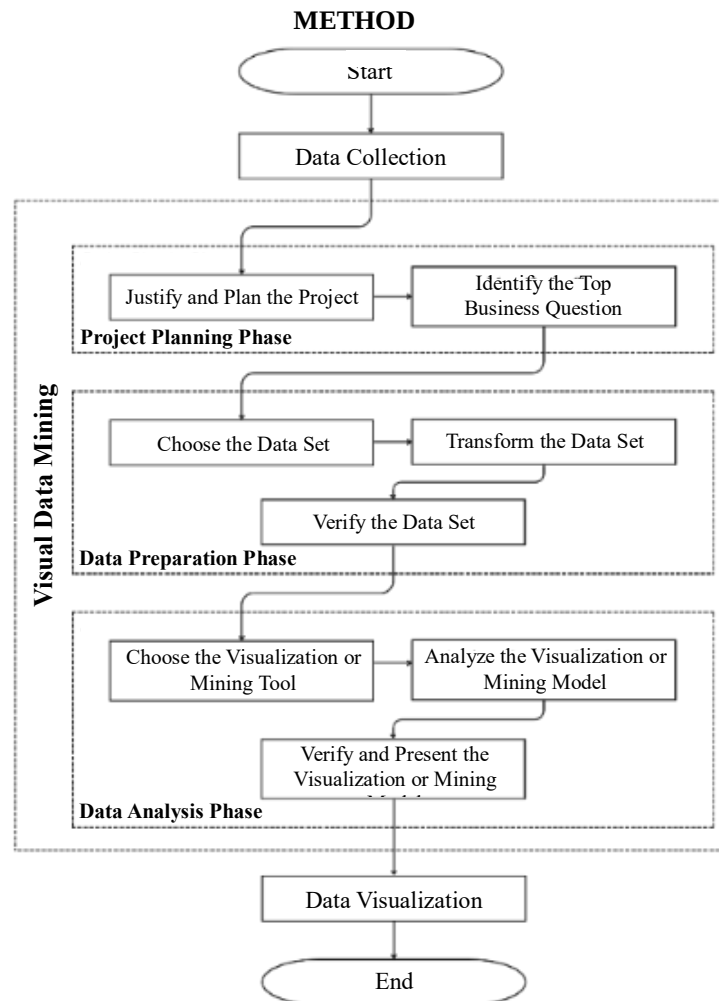


Fig. 2 Research Flow

This research was conducted using the Visual Data Mining (VDM) approach, beginning with data collection through interviews, observations, and literature studies to understand the types, quality, and processing flow of the UKBI data. The collected data were then prepared through selection, transformation, and verification to ensure analytical suitability. Subsequently, visualization techniques and data mining methods—including the K-Means algorithm to identify clustering patterns of scores in each section—were applied, evaluated, and interpreted to ensure the accuracy of the results. The final outcomes are presented in a web-based interactive dashboard that visualizes the UKBI test-takers' achievements in Jambi Province, allowing the research findings to be accessed, explored, and utilized as a practical contribution to understanding language proficiency patterns in the region.

Data collection was carried out through observations and interviews to obtain a comprehensive understanding of data management and visualization needs for UKBI at Balai Bahasa of Jambi Province. Observations were conducted by directly reviewing the workflow, data processing mechanisms, and the forms of visualization that had been published through official social media channels. The findings indicate that the existing visualizations remain static and are not yet capable of illustrating the dynamics of the data in depth, thereby necessitating a more interactive and informative approach. Additional information was gathered through interviews with the person in charge of the UKBI KKLP to identify visualization needs, obtain explanations regarding plans for developing data presentations, and collect the UKBI data to be used in this research visualization. Furthermore, a literature study was conducted by examining various relevant theories and concepts from scientific journals, books, magazines, and online articles to build the theoretical foundation for the report. This literature review provides conceptual support related to data visualization and serves as

the basis for understanding and formulating the approach to Visual Data Visualization of UKBI Test-Takers' Achievement.

Project Planning Phase

The initial phase of this research focused on the VDM (Visual Data Mining) Project Planning, which began with the establishment of the project's objectives and rationale. This process commenced with the main justification: the limitations in the visualization of UKBI participant achievements in Jambi Province, which have so far only been presented in the form of simple charts on social media. Based on this gap, the research was defined as a Pilot VDM project, aiming to develop an interactive dashboard as an initial analytical solution, aligned with the needs of Balai Bahasa of Jambi Province. Subsequently, the Identification of Top Business Questions was carried out, where the researchers mapped the key questions that the visualization must answer, including the distribution of proficiency levels by region, UKBI performance trends over time, and patterns of test results. This question mapping serves as the foundation for the dashboard design, ensuring that the visual data output is relevant and capable of supporting the decision-making process by the Jambi Province Language Center.

Data Preparation Phase

The Data Preparation Phase within the VDM methodology begins with the Dataset Selection stage, where UKBI results data for Jambi Province from 2021 to 2024 were collected through direct coordination with the Balai Bahasa of Jambi Province. The selected dataset includes comprehensive information such as proficiency levels (Exceptional to Limited), profession, city/regency of origin, and scores per test section, all of which are crucial for analyzing proficiency patterns. Subsequently, in the Data Transformation stage, all worksheets were merged into a single integrated dataset. The transformation process was performed computationally using Python (specifically the Pandas library) for data cleansing, including the removal of duplicates, standardization of text formats, and the processing of date of birth and test date variables to calculate additional analytical attributes such as age and test year. The result of this process is a clean, uniform, and analysis-ready dataset. Finally, a thorough Data Verification was conducted to confirm the accuracy, consistency, and validity of all transformed data, ensuring reliable visualization results to support decision-making.

Table 1. Number of UKBI Participants

Years	Number of UKBI Participants
2021	595 Participants
2022	2.633 Participants
2023	2.609 Participants
2024	3.616 Participants

Data Analysis Phase

The final phase of the VDM methodology focuses on Model Analysis and Presentation, which integrates the K-Means clustering technique with the development of an interactive dashboard. In the tool selection stage, ApexCharts.js was chosen for descriptive visualization due to its flexibility in presenting annual trends, category distribution, and the geographical spread of UKBI performance. Simultaneously, the K-Means algorithm was applied to the normalized data to identify participant grouping patterns, with the optimal number of clusters determined using the Silhouette Score and the Davies–Bouldin Index. The clustering results were then visualized using scatter plots and spider charts to support in-depth interpretation. The user interface (UI) development was carried out using Laravel, HTML, JavaScript, and Tailwind CSS, supported by Leaflet.js for regional mapping. The Verification and Presentation stage involved a series of validation steps with staff from the Jambi Province Language Center to ensure that the dashboard was accurate, informative, and easy to use. Once verified, the dashboard was integrated into the Language Center's environment as a decision-support tool.

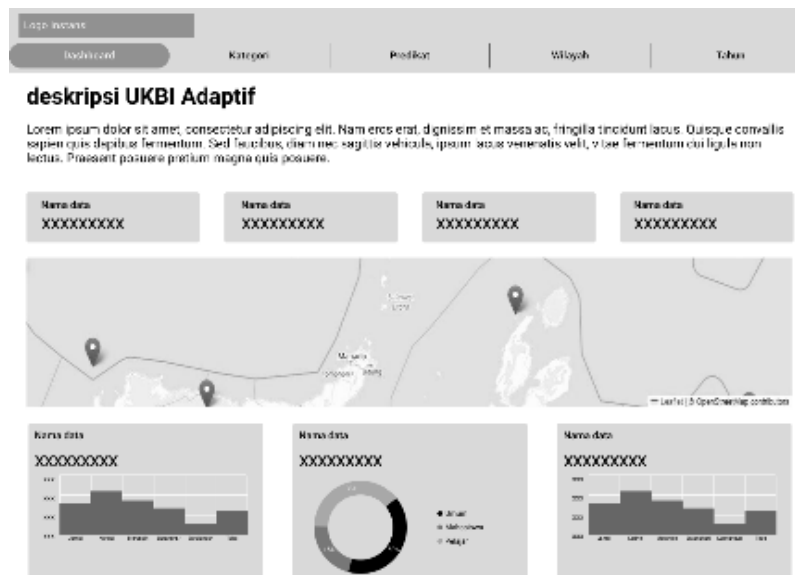


Fig. 3 Low Fidelity Wireframe

RESULT

Project Planning Phase

Justify and Plan the Project

The initial stage of this research focused on the Justification and Planning of the VDM (Visual Data Mining) Project, which was motivated by an identified analytical gap. The core justification for this project lies in the limitations of the visualization of UKBI participant achievements in Jambi Province, which have historically been presented only as simple static charts, thus being deemed suboptimal for in-depth trend analysis and data-driven decision-making. In response to this deficiency, the study was designated as a Pilot VDM project, with the explicit goal of developing an interactive dashboard as an initial analytical solution that directly supports the needs of Balai Bahasa of Jambi Province in monitoring and evaluating the regional language proficiency profile.

Identify and Plan the Project

This process involved mapping the key questions that the visual data output must answer to support decision-making. Specifically, the visualization must be capable of revealing the distribution of UKBI proficiency levels (from Exceptional to Limited) based on the city/regency in Jambi Province. Furthermore, an analysis is required to monitor the performance trends of the adaptive UKBI from 2021 to 2024 and to identify the hidden grouping patterns (clustering) of participant scores across the various test sections. Finally, the visualization must provide insights into the specific proficiency profiles of certain professional groups (e.g., Students, Teachers, Lecturers). Mapping these questions served as the foundation for the dashboard design, ensuring the relevance and utility of the analytical solution developed.

Data Preparation Phase

Choose the Data Set

The Dataset Selection stage in the Data Preparation Phase of the VDM methodology focused on the collection of secondary data. The data utilized were the results of the Adaptive Indonesian Language Proficiency Test (UKBI Adaptif) in Jambi Province, spanning the years 2021 to 2024. This dataset is voluminous, comprising over 10,000 rows, and contains key variables essential for the analysis. These variables include the proficiency level, participant profession, city/regency of origin, and detailed scores per test section (Listening, Responding to Rules, Reading, and Writing), enabling an in-depth analysis of regional language proficiency patterns.

Transform the Data Set

The Dataset Transformation stage is a crucial step in the VDM Data Preparation Phase, which was executed computationally using the Python programming language with the Pandas library. This process began with the merging of all UKBI test results worksheets into a single integrated dataset. Subsequently, a thorough data cleansing was performed, encompassing the removal of duplicate entries and the standardization of text formats to ensure consistency. Furthermore, the transformation process also included the calculation of additional attributes essential for analysis, such as participant age and the year of the test, which were derived from the date of birth and test date variables. All these steps aimed to yield a clean, uniform, and analysis-ready dataset.



Nama Peserta	Kota	Jenis Kelamin	Seksi I	Seksi II	Seksi III	Usia	Tahun Ujian
Sri Yanti	KABUPATEN BUNGO	Perempuan	290	344	395	27	2021
Huriyah Padhilah Anasti	KABUPATEN KERINCI	Perempuan	245	584	545	27	2021
Maharani Dwi Putri Asriati	KABUPATEN KERINCI	Perempuan	260	536	380	28	2021
Dedi Saputra	KABUPATEN KERINCI	Laki-laki	320	536	620	27	2021
Ria Elva Diana	KABUPATEN MERANGIN	Perempuan	215	536	215	26	2021
Larasati	KABUPATEN TANJUNG JABUNG BARAT	Perempuan	230	584	470	27	2021
Elva Yusanti, M.Hum.	KOTA JAMBI	Perempuan	695	752	590	51	2021
Sarwono, S.Pd.	KOTA JAMBI	Laki-laki	440	416	545	53	2021
ILSA DEWITA PUTRI SORAYA, S.S.	KOTA JAMBI	Perempuan	455	776	725	46	2021
Ifqi Zahwa Pratiwi	KABUPATEN BATANG HARI	Perempuan	695	560	725	22	2021
Ranti Rizkia Taqwiyyah	KABUPATEN TEBO	Perempuan	575	752	620	22	2021
Muhammad Hafif	KOTA JAMBI	Laki-laki	530	560	470	22	2021
M. Farhan Aulia	KOTA JAMBI	Laki-laki	560	392	575	22	2021
Sri Yanti	KABUPATEN BUNGO	Perempuan	365	368	290	27	2021
Huriyah Padhilah Anasti	KABUPATEN KERINCI	Perempuan	620	680	650	27	2021
Maharani Dwi Putri Asriati	KABUPATEN KERINCI	Perempuan	365	392	350	28	2021
Ria Elva Diana	KABUPATEN MERANGIN	Perempuan	425	560	395	26	2021
Larasati	KABUPATEN TANJUNG JABUNG BARAT	Perempuan	515	344	380	27	2021
Ichha Vidia Ramanza	KABUPATEN BATANG HARI	Perempuan	425	392	470	26	2021
Desi Ariani Putri Br. Purba	KABUPATEN BATANG HARI	Perempuan	440	440	455	25	2021

Fig. 4 Dataset Cleansed

Verify the Data Set

The Data Verification stage is the final step in the Data Preparation Phase, aimed at ensuring the accuracy and consistency of the transformed dataset. The results of this verification process indicated that the dataset was effectively free from significant missing values and ready for use. With the guaranteed level of data integrity, the dataset was confirmed as valid to proceed to the analysis stage, thereby ensuring the reliability and trustworthiness of the visualization results and research conclusions.

Data Analysis Phase

Choose the Visualization or Mining Tool

The Selection of Visualization and Data Mining Tools stage served as the initial step in the Data Analysis Phase. For descriptive visualization purposes, the ApexCharts.js library was chosen due to its capability to dynamically present annual trends and the distribution of proficiency categories. For geographical visualization, Leaflet.js was utilized for regional mapping, allowing for the representation of the distribution of test participants and UKBI score achievements at the city/regency level. Meanwhile, to meet the analytical objectives, the K-Means Algorithm was selected as the primary data mining technique, applied to identify and uncover hidden clustering patterns of test participants based on their test score vectors. This combination of tools ensured a comprehensive analytical approach, ranging from descriptive data exploration to in-depth pattern discovery.

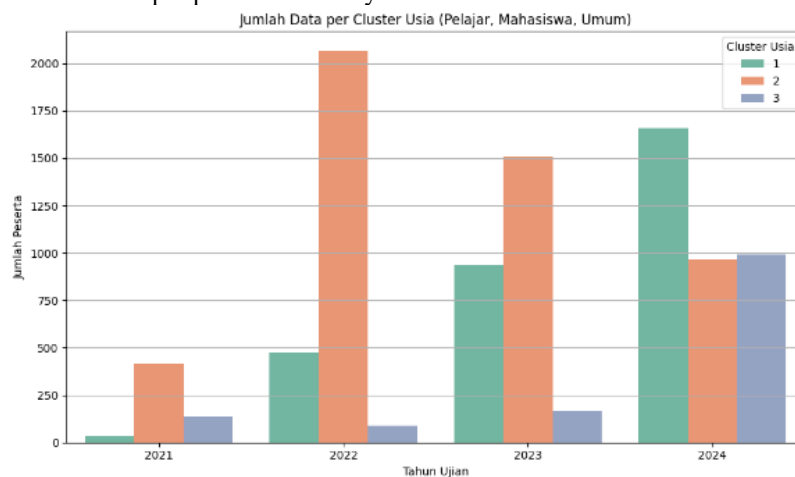


Fig. 5 Bar Chart Amount of Data Based on Age Clusters

The bar chart shows how the number of participants in each age cluster changes across the UKBI test years from 2021 to 2024. The second cluster consistently records the highest participation, while clusters one and three show noticeable increases in the later years.

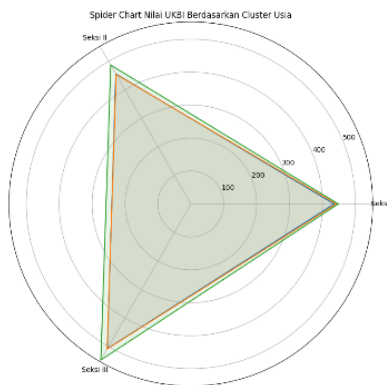


Fig. 6 Spider Chart of UKBI Scores by Age Clusters

The spider chart compares the average UKBI scores of each age cluster across the three test sections, showing that their performance patterns are relatively similar. Cluster groups display only slight variations in each section, indicating consistent proficiency levels across ages.

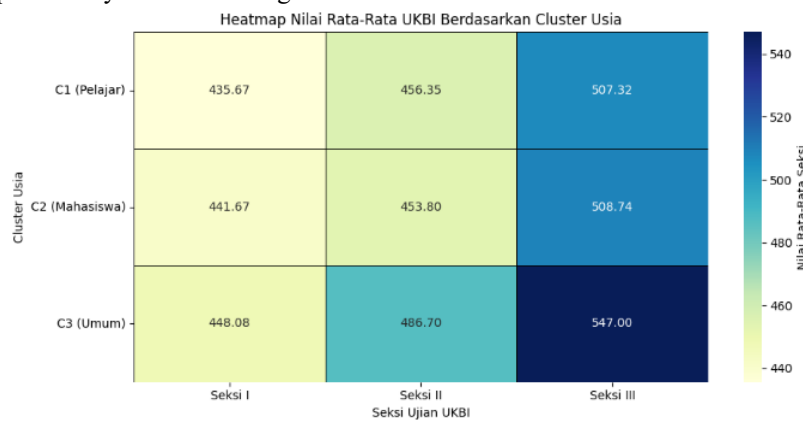


Fig. 7 Heatmap of Average UKBI Scores Based on Age Clusters

The heatmap displays the average UKBI scores for each age cluster across the three test sections, revealing distinct performance patterns. Cluster three consistently achieves the highest scores, especially in Section III, while clusters one and two show relatively similar results in the earlier sections.

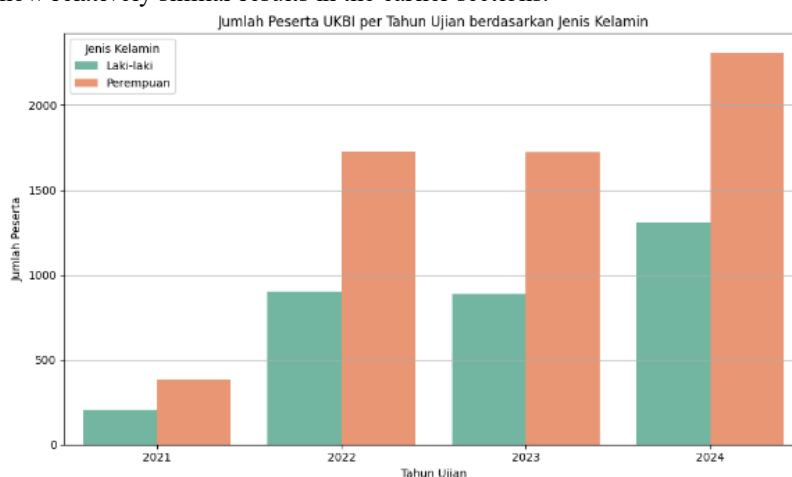


Fig. 8 Bar Chart Amount of Data by Gender

The bar chart illustrates the yearly number of UKBI participants by gender, showing a consistent rise for both groups from 2021 to 2024. Female participants appear to increase more rapidly each year, maintaining higher totals compared to male participants.



Heatmap Nilai Rata-Rata UKBI Berdasarkan Jenis Kelamin

Jenis Kelamin	Seksi I	Seksi II	Seksi III
Laki-laki	434.15	446.69	501.31
Perempuan	444.02	466.29	520.53

The heatmap compares the average UKBI scores of men and women across three test sections, showing that both groups score progressively higher from Section I to Section III. It also highlights that women slightly outperform men in every section.



Fig 11 shows a dashboard explaining the Adaptive UKBI, outlining the test's purpose, its five sections, and overall participant statistics such as total test-takers, teachers, students, and the general public. It also includes a regional map of test locations and bar charts that break down participant numbers by score category and type.



Fig. 12 Category Page

The dashboard presents the number of UKBI participants from several groups such as pupils, students, university students, and the general public, along with a line chart that shows how each group changes over time. It also features two pie charts that illustrate the share of participants within the student group and the general public group.

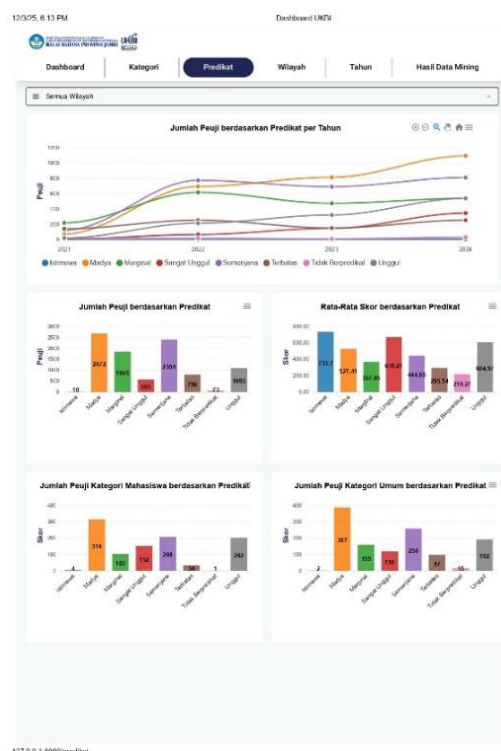


Fig. 13 Predikat Page

The dashboard shows how UKBI participants are distributed across different proficiency levels each year, illustrated through a line chart that highlights changes over time. It also includes several bar charts that display participant counts and average scores for each proficiency level in the overall group, the student group, and the general public group.

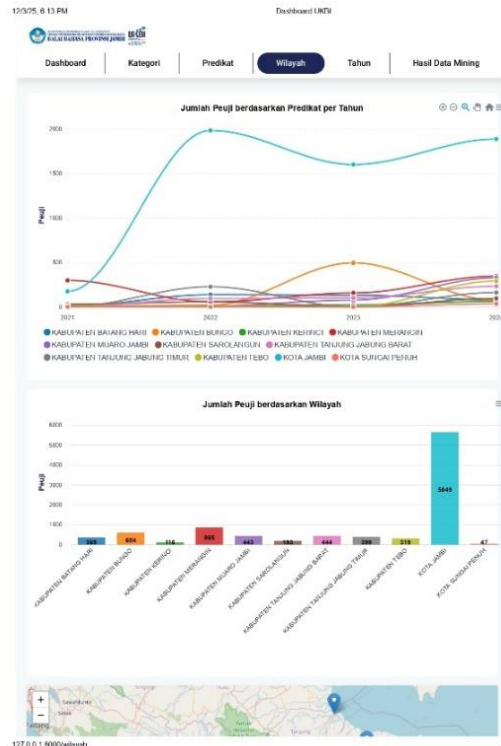


Fig. 14 Region Page

The dashboard illustrates annual UKBI participant trends across various regions, with one region showing a significantly higher rise than the others. It also presents a bar chart that compares the total number of participants in each region, highlighting clear differences in regional participation.

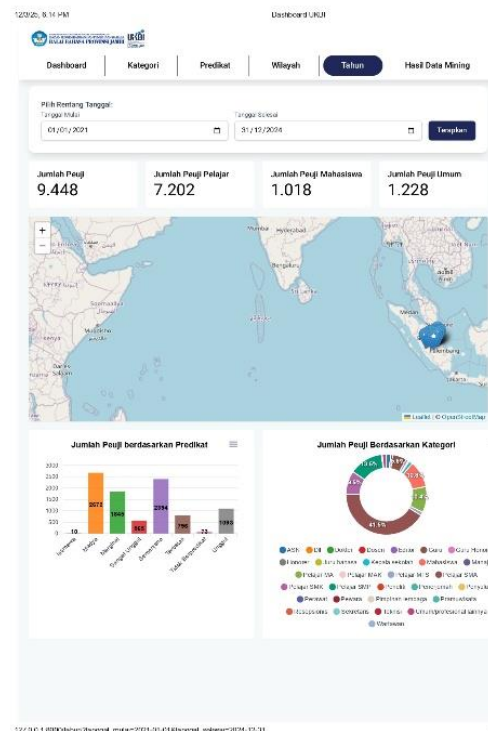


Fig. 15 Year Page

The dashboard summarizes UKBI participant data within a selected date range, showing totals for pupils, students, university students, and the general public. It also includes a map of test locations along with bar and doughnut charts that display participant distribution by proficiency level and category.

Analyze the Visualization or Mining Model

The temporal trend analysis of adaptive UKBI achievements from 2021 to 2024, presented using the ApexCharts.js Line Chart, shows that the majority of participants consistently fall within the Intermediate (Madya) category. The highest average score, 580, occurred in 2023 and remained within the Intermediate category. This significant increase was primarily driven by the high participation rate and good achievements from the student group during the beginning of that year. However, when sectional analysis was performed, the lowest average score was found in the Responding to Rules section, a finding that indicates the necessity for program intervention to enhance grammar mastery in the study area.

Following data normalization, the K-Means algorithm was applied to uncover hidden language proficiency grouping patterns. Based on the evaluation of the Silhouette Score, the optimal number of clusters successfully identified three distinct proficiency patterns. Cluster 1 (The Writing Performer Group), accounting for approximately 15% of participants, was characterized by very high scores in the Writing and Reading sections, and was predominantly composed of Lecturers/Researchers. Cluster 2 (The Balanced Intermediate Group), representing the majority (around 60%), showed even and consistent scores in the Intermediate/Superior range across all sections, dominated by Students and University Students. Meanwhile, Cluster 3 (The Listening Struggler Group), comprising about 25% of participants, exhibited very low scores in the Listening section but performed relatively better in the Reading section, dominated by non-education professions and indicating a need for intensive audio-based training.

The analysis of regional distribution, visualized using Leaflet.js, revealed geographical variations in UKBI achievement. Specifically, Muaro Jambi Regency stood out with a relatively higher percentage of participants in the Superior and Exceptional categories, despite a small total number of participants. Conversely, Jambi City was the region with the largest volume of participants, but its average proficiency score was at the lower boundary of the Intermediate category, highlighting a disparity between participation volume and achievement quality.

Verify and Present the Visualization or Mining Model

The final stage of the VDM methodology involved the Verification and Validation of the results through usability testing. This testing was carried out by involving the staff of the Balai Bahasa of Jambi Province to evaluate the dashboard's functionality, clarity, and overall user experience. Based on the feedback obtained, the UKBI visualization dashboard was deemed successful and officially accepted by the Jambi Province Language Center as an informative and effective tool to support policy analysis and data-driven decision-making in the region.

DISCUSSION

The implementation of the Visual Data Mining (VDM) methodology and the K-Means Algorithm proved effective in overcoming the limitations of static UKBI data visualization, providing previously unavailable actionable intelligence. Through VDM, descriptive analysis was augmented by the significant finding of three hidden proficiency clustering patterns. Notably, Cluster 3 (The Listening Struggler Group), dominated by non-education professions, indicated a specific problem in listening skills, a finding that scientifically validates the need for highly focused program intervention (e.g., intensive audio-based training). Furthermore, geographical analysis revealed a disparity in regional quality; Jambi City, despite having the largest participation volume, showed an average achievement at the lower boundary of the Intermediate (Madya) category, contrasting with the superior achievements in Muaro Jambi Regency. This finding provides a strategic foundation for the Jambi Province Language Center to allocate resources more proportionally and targetedly, establishing VDM as an essential tool for evaluation and decision-making.

CONCLUSION

This research successfully developed an Interactive Visual Data Mining Dashboard that now serves as an official Decision Support tool for the Jambi Province Language Center, mapping UKBI proficiency profiles from 2021 to 2024. Through the integration of K-Means clustering, the dashboard successfully uncovered three distinct proficiency profile clusters, validating the necessity for detailed, non-generalized language policies. Although this study was limited by its reliance on secondary quantitative data—excluding external qualitative factors—its benefit lies in providing exploratory data intelligence to identify intervention priorities. Therefore, further studies are recommended to integrate predictive analysis and utilize the clustering findings (especially the low-performing Cluster 3) as a basis for in-depth qualitative studies to reveal the root socio-pedagogical issues.

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