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Assessment Clusterization Teacher Performance with K-Means Algorithm Clustering and Agglomerative Hierarchical Clustering (AHC)

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Abstract: Research This aims to do clustering evaluation teacher performance with the application of the K-means clustering algorithm and agglomerative hierarchical clustering (AHC). Background study This is based on needs to increase quality teaching through analysis and evaluation and better teacher performance. The methods applied involving assessment data collection performance from teachers in the environment education local, processed using a second algorithm The results of the research show that the silhouette score value for K-means reached 0.364, while AHC produced a value 0.343. With Thus, K-means is proven more effective in grouping assessment data and teacher performance compared to AHC. The conclusion of the study This confirms the importance of implementation of the K-means algorithm to get more insight into good evaluation teacher performance. Author Ready to do repairs or revisions to the manuscript. This is in accordance with comments and suggestions from the reviewer as a condition beginning. For processing more, carry on.

Keywords: Agglomerative Hierarchical Clustering (AHC); Clustering Algorithm; Data Mining; Indonesian Education, Silhouette Score; K-Means; Teacher Performance Evaluation

INTRODUCTION

In the era of increasingly developing education, improving the quality of teacher performance is one of the main focuses in efforts to improve the quality of education in Indonesia. Hartono et al. (2023) assume that in the era of globalization and technological advances, demands for the quality of education are increasing. Teachers are not only expected to deliver lesson materials well but also to become learning facilitators who are able to develop the creativity and critical thinking of students. In this context, teacher performance evaluation is a vital instrument to ensure that the learning process runs optimally (Rusmiyanto et al. (2023); Wulantari et al. (2023); Sari & Ningsih (2022)(Kamaruddin et al., 2024). Poor teacher performance can reduce the quality of education and hinder the achievement of the vision and mission of education. Therefore, teacher performance must be managed and maintained properly so that it does not decline. In fact, it must always pay attention to continuous improvement. The Head of Madrasah, as a manager, is responsible for the running of the educational process, administration, supervision, evaluation, and coaching of teachers and education personnel, and the utilization and maintenance of facilities and infrastructure (Hasan, 2022).

Teacher effectiveness is the result of an assessment of the process and effectiveness of teachers in carrying out their duties. The purpose of teacher performance evaluation is to assess the performance of each teacher in their main duties as part of career and position development. Alwi, Syafaruddin. (2001) theoretically the purpose of evaluation is classified into being evaluated based on its nature and development, where the evaluation performance should be: 1) Evaluation results are used as the basis for giving rewards; 2) Evaluation results are used as the basis for personal decisions, 3) Evaluation results are used as the basis for evaluating the selection system. Even though it is development-oriented, the evaluator must do the following: 1) actual individual achievement; 2) individual weaknesses that hinder performance; 3) achievements that are developed. Each institution has its own teacher performance assessment process and procedures, which are regulated in the

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institution's performance regulations (MELELO, 2023). Various assessment methods have been developed, one of which is a data-based approach using clustering techniques.

LITERATURE REVIEW

The process of clustering data involves dividing it up into multiple groups or clusters so that the data within a group is the most similar to the data outside of it. In this case, the similarity between two objects is measured numerically. The similarity score will increase if the two objects being compared exhibit a high degree of resemblance (Ummah, 2019). Clustering is one of the data mining methods (Gustientiedina et al., 2019), which has the ability to group data into a group based on similar characteristics, while data with different characteristics will be grouped into other groups (Pamungkas et al., 2023). The K-Means Clustering and Agglomerative Hierarchical Clustering (AHC) algorithms are two clustering techniques that are often used in data processing. Both have different approaches to grouping data, which can provide valuable insights into teacher performance assessment.

Before starting this research, it is important to review previous studies that have discussed teacher performance assessment and the use of clustering techniques. This study successfully clustered lecturer effectiveness employing the K-Means Clustering technique and data mining techniques. From 983 student data analyzed, it was found that 31.74% of lecturers were categorized as very good, 40.79% good, 19.23% quite good, and 8.24% less good. By using the Knowledge Discovery in Database (KDD) method, this study proved the effectiveness in evaluating lecturer performance, with a Davies-Bouldin Index (DBI) value of 0.270. This value indicates a good level of accuracy in clustering results (Dewi et al., 2022). Other related research using the K-Means Clustering algorithm was conducted by Ismail Virgo (2020) regarding the clustering of lecturer attendance levels. The K-Means Clustering algorithm was utilized to analyze the outcomes of the lecturers' division into three groups: 72 courses instructed by non-civil servant lecturers in the group that meets infrequently (4.7650%), 69 courses instructed by non-civil servant lecturers in the group that meets moderately (4.5665%), and 1370 courses instructed by non-civil servant lecturers in the group that meets carefully (90.6684) (Virgo, Defit, and Yunus 2020)(Virgo et al., 2020). Relevant literature shows that the use of this method can help in the process of evaluating and improving the quality of education.

The problem statement in this study focuses on the main question: Is the effectiveness of using the K-Means Clustering and Agglomerative Hierarchical Clustering algorithms able to cluster teacher performance assessments well? This research seeks to identify the comparison of the results obtained from the two algorithms in grouping teacher performance assessment data and analyzing the characteristics of each cluster formed.

The purpose of this study is to provide a deeper understanding of how clustering techniques can be applied in the context of teacher performance assessment. Thus, it is hoped that this study can be a reference and provide a significant contribution to the development of assessment methods in the world of education (Liu & Wang, 2021(Selly et al., 2023).

The contribution of this research are anticipated to offer practical solutions for education in Indonesia by providing recommendations for more effective evaluation strategies. In addition, the findings from this study are also intended to be a reference point for educational institutions and other stakeholders in designing more targeted teacher quality development programs (Nurjannah & Nurhadi, 2020).

Through this research, we hope to provide a clearer picture of the dynamics of teacher performance in Indonesia and applicable solutions to advance educational quality. This study is committed to presenting a comprehensive and data-based analysis, so that the results obtained can be scientifically accounted for and beneficial for the development of education in the country.

METHOD

The type of research used in this study is quantitative research, which focuses on data analysis through statistical processing and the application of cluster algorithms. The object of the study consists of teacher performance assessment data at the Office of the Ministry of Religion for Madrasah Education, which was taken in the period from November 2023 to April 2024. Data were collected through a questionnaire targeting 1,944 teachers by measuring various aspects of performance, such as personality, pedagogical, social, discipline, and professional.

This study uses one dependent variable, namely teacher performance, which is measured through five indicators: personality, pedagogy, social skills, discipline, and professionalism. In addition, there are five independent variables, namely personality, pedagogic, social, discipline, and professional, each of which is measured based on relevant aspects.

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TABLE 1 VARIABLES STUDY

Variable Types	Variable Name	Information	Measurement Scale
Dependent	Teacher Performance	Evaluation overall teacher performance based on five aspects main.	Interval
Independent	Personality	Evaluation about teacher personality, such as attitude, ethics and abilities adaptation.	Interval
	Pedagogy	Teacher competence in management learning and methods teach.	Interval
	Social	Teachers' ability in communicate and build connection good social.	Interval
	Discipline	The level of teacher compliance with rules and management time in carry out his duties.	Interval
	Professional	Ability professional teacher in convey materials and use the right approach.	Interval

Data collection was conducted through interviews and direct observation at the Office of the Ministry of Religious Affairs for Madrasah Education. Furthermore, the collected data will be analyzed using two cluster algorithms, namely K-Means Clustering and AHC. To help with comprehension and visualization of the obtained cluster results, the outcomes of the analysis will be presented as tables and graphs.

Data preprocessing is done to ensure the quality of the data used is in accordance with the applied algorithm. This process involves collecting data from interviews and direct observations, cleaning the data to remove irrelevant data, transforming the data into a numeric format, and normalizing the data so that all variables have the same scale. This step aims to improve the accuracy of the clustering results.

The research steps can be presented in the following flowchart:

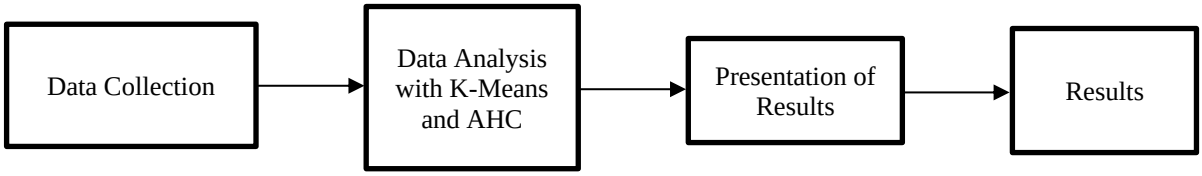

Fig. 1 Research Flow Diagram.

Data obtained through: interview method and direct observation to the Office of the Ministry of Religion for Madrasah Education, direct observation at the Office of the Ministry of Religion for Madrasah Education to collect additional data, performance assessment document from the Office of the Ministry of Religion for Madrasah Education.

The collected data will be analyzed using two clustering algorithms, namely K-means clustering, to divide the dataset into k groups based on similar characteristics. Agglomerative Hierarchical Clustering (AHC) to analyze the relationship between groups and form a cluster hierarchy. The analysis was carried out using Google Colab software.

How to Present Analysis Results? The findings of the clustering analysis will be presented in the form scatter plot diagram for visualization of cluster distribution, summary table showing the characteristics of each cluster, dendrogram diagram for AHC depicting the relationships between clusters.

The findings of this study are represented as grouping student value data based on the outcomes of the learning process assessment utilizing the K-Means algorithm.

Analyzing and extracting knowledge automatically using one or more machine learning techniques is called data mining. Another definition is that, according to the Gatner Group, the process of analyzing massive amounts of data that have been stored in storage and applying pattern recognition techniques, such as statistical and mathematical methods, to identify significant relationships, patterns, and trends is known as data mining(Parlambang & Fauziah, 2020)(Syafrinal & Febrianti, 2023).

K-Means Clustering Algorithm is a Data Mining analysis method where the modeling process is unsupervised, and how to group data based on partitions. The K-Means technique divided the data into multiple groups, each of which had distinct characteristics from the others while sharing similarities with the others. With the intention of

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maximizing the differences with other clusters and minimizing the differences in each piece of data within one cluster(Atiqul Mutaqin & Andriyani, 2022).

The steps in the k-means algorithm can be described as follows determination of the number of clusters (k) in the data set, initialize the center value (Centroid).

The establishment of the Centroid value at the beginning is done randomly and then iterated using the formula as in Equation (1).

$$V_{ij} = \frac{1}{Ni} \sum_{k=0}^{Ni} Xkj \quad (1)$$

Information:
Vij is the average of the Centroid of the i-th cluster for the j-th variable.
Ni is the number of members of the ith cluster
i, k is the cluster index
j is the variable index
Xkj is the k-th data value of the j-th variable for that cluster.

Calculation of the closest distance to the Centroid on each record. In this study, Euclidean Distance is used, with the equation as presented (2).

$$De = \sqrt{(xi - si)^2 + (yi - ti)^2} \quad (2)$$

Information:
De refers to Euclidean Distance
I refers to the number of objects
(x, y) are the object coordinates
(s, t) is the Centroid Coordinate

Grouping objects based on the closest distance to the Centroid. Iterations from Steps 3 to 4 are repeated until the optimal value at the Centroid is reached(Fitri et al., 2023).

AHC (Agglomerative Hierarchical Clustering) is a technique for conducting data analysis exploration by grouping data into a collection of groups called clusters(Ulfatul Syahara et al., 2024). The implementation stages carried out during the processing of datasets that have been collected and processed with the proximity of the Agglomerative Hierarchical Clustering algorithm are as follows(Iyan Yulianti et al., 2023):

Single Linkage (Nearest Neighbor Method)

$$d\,(UV)W = \min(d\,UW, d\,VW) \quad (3)$$

Complete Linkage (Furthest Neighbor Methods)

$$d\,(UV)W = \max(d\,UW, d\,VW) \quad (4)$$

Average Linkage (Between Groups Methods)

$$d\,(UV)W = \frac{d_{(UW)} + d_{(VW)}}{n_{(UV)} n_w} \quad (5)$$

RESULT

The data utilized in this analysis are samples taken from the teacher performance assessment data for the 2023 academic year. The teacher performance assessment dataset consists of the attributes SEQUENCE NO, READY ID, PEG ID, ACTIVE STATUS, PERSONALITY ASSESSMENT, SOCIAL ASSESSMENT, PEDAGOGIC ASSESSMENT, DISCIPLINE ASSESSMENT, PROFESSIONAL ASSESSMENT. There are 1944 teacher data in the sample that will be tested. Examples of teacher data used can be seen in table 1.

TABLE II. RESEARCH DATASET

SEQUENCE NO.	READY ID	PEG ID	ACTIVE STATUS	PERSONALITY ASSESSMENT	SOCIAL ASSESSMENT	PEDAGOGICAL ASSESSMENT	DISCIPLINE ASSESSMENT	PROFESSIONAL ASSESSMENT
1	10816493	10603287186001	1	80	88	88	90	80
2	10816514	10606062100002	1	78	85	80	80	88
3	10803157	10645874192002	1	80	80	85	88	80

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4	10814951	10800829190001	1	80	85	88	80	88
5	10816574	10802704100001	1	85	85	78	85	80
6	10816565	10802720100003	1	80	88	85	80	80
7	10815821	10802729100001	1	88	85	80	85	78
8	10816493	10802737100006	1	85	80	85	80	88
9	10809480	10802748100008	1	80	85	88	80	88
10	10815825	10802762100005	1	80	85	88	80	88
11	10814895	10802762100013	1	80	85	88	80	80

Based on the existing dataset, then using the Python tool with Google Colab, enter the teacher performance assessment dataset and see the correlation between the 5 variables used, the results of the existing variable correlation is illustrated in Figure 2.

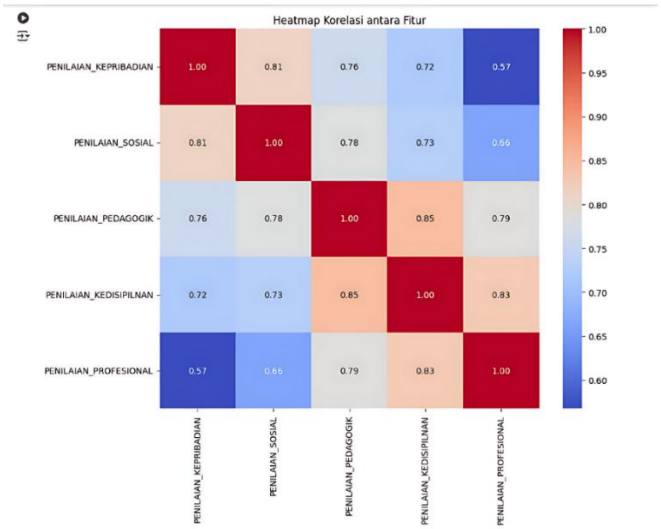

Fig. 2 Variable Correlation Results

Next, form statistics descriptive based on K-Means and AHC clusters from the results of Teacher Performance Assessment data visualization based on the Teacher Performance Assessment dataset. The results of cluster formation using python is illustrated in Figure 3.

```
Statistik Deskriptif per Cluster K-Means:
        PENILAIAN_KEPRIBADIAN                                          \
                        count       mean       std   min   25%   50%   75%
Cluster
0                       531.0  71.265537  3.485701  60.0  70.0  71.0  73.0
1                       786.0  75.488550  3.461600  62.0  73.0  75.0  78.0
2                       627.0  82.003190  3.089711  70.0  80.0  82.0  84.0

            PENILAIAN_SOSIAL                ... PENILAIAN_KEDISIPILNAN        \
         max            count       mean  ...                   75%   max
Cluster                                    ...
0       88.0            531.0  71.079096  ...                  73.0  81.0
1       88.0            786.0  75.743003  ...                  78.0  88.0
2       90.0            627.0  82.824561  ...                  85.0  95.0

        PENILAIAN_PROFESIONAL                                          \
                        count       mean       std   min   25%   50%   75%
Cluster
0                       531.0  70.749529  4.072385  48.0  70.0  72.0  73.0
1                       786.0  77.352417  3.143162  64.0  75.0  77.0  79.0
2                       627.0  83.299841  3.766260  70.0  81.0  83.0  85.0


          max
Cluster
0        82.0
1        91.0
2       100.0

[3 rows x 40 columns]
```

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```
Statistik Deskriptif per Cluster:
            PENILAIAN_KEPRIBADIAN                                          \
                            count       mean       std   min   25%   50%
Cluster_AHC
1                           797.0  71.796738  3.095034  60.0  70.0  72.0
2                           645.0  77.223256  3.345028  62.0  75.0  77.0
3                           502.0  82.790837  2.642746  75.0  80.0  82.0

                    PENILAIAN_SOSIAL                ...  \
                 75%   max            count       mean  ...
Cluster_AHC                                         ...
1           73.0  88.0              797.0  71.899624  ...
2           80.0  88.0              645.0  77.693023  ...
3           85.0  90.0              502.0  83.250996  ...

            PENILAIAN_KEDISIPILNAN       PENILAIAN_PROFESIONAL             \
                               75%   max                 count       mean
Cluster_AHC
1                             75.0  81.0                 797.0  72.800502
2                             80.0  87.0                 645.0  78.381395
3                             86.0  95.0                 502.0  83.701195

                 std   min   25%   50%   75%    max
Cluster_AHC
1           4.555807  48.0  71.0  73.0  76.0   85.0
2           4.037514  64.0  76.0  78.0  80.0   93.0
3           3.546998  72.0  81.0  83.0  86.0  100.0

[3 rows x 40 columns]
```

Fig. 3 Statistics descriptive based on K-Means and AHC clusters.

DISCUSSIONS

After the number of clusters is determined, the next stage is to create groups and clusters based on the teacher performance assessment dataset so that the existing teacher performance assessment dataset forms 3 predetermined clusters. The results of the visualization of the teacher performance assessment data cluster is illustrated in Figure 4.

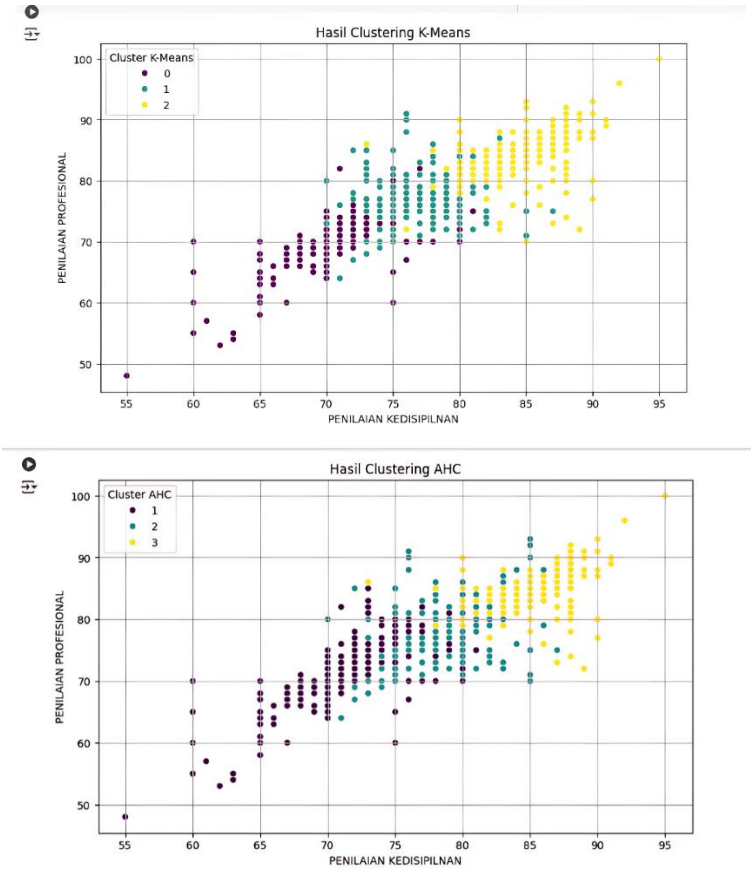

Fig. 4 Cluster Results of K-Means and AHC Algorithms

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As indicated by the findings of the teacher performance assessment data cluster using the K-Means method, cluster 0 consisted of 531 teachers, cluster 1 consisted of 786 teachers, and cluster 2 consisted of 627 teachers. The results of the teacher performance assessment data cluster using the AHC method resulted in cluster 1 consisting of 797 teachers, cluster 2 consisting of 645 teachers, and cluster 3 consisting of 502 teachers. The cluster results using python is illustrated in Figure 5.

```
Jumlah Penilaian Kinerja Guru per Cluster K-Means:
Cluster
1    786
2    627
0    531
Name: count, dtype: int64
```

```
Jumlah Penilaian Kinerja Guru per Cluster:
Cluster_AHC
1    797
2    645
3    502
Name: count, dtype: int64
```

Fig. 5 Cluster Results of Number of Teacher Performance Assessments

This testing stage determines the best cluster in K-Means using the Elbow Method by calculating the Sum Square Error (SSE) value and then visualizing it in the form of a graph where the results of the SSE calculation are depicted in the form of an elbow and the value that has a drastic decrease is the optimal number of K.

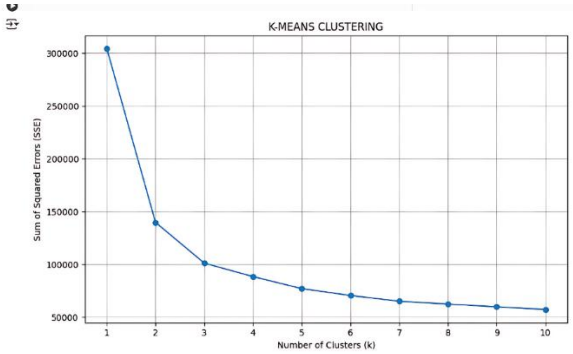

Fig. 6 Elbow Method Test Results

Grounded in the evaluation findings employing the elbow method, the number of good clusters used is 3 clusters, so in this study 3 clusters were used, that is cluster 0, cluster 1, and cluster 2.

At this stage, determining the best number of clusters for Agglomerative Hierarchical Clustering is done using a dendrogram. A dendrogram is a visual representation of the clustering process that shows how data is combined hierarchically. By observing the dendrogram, we can determine the optimal cut-off level based on the distance between the merging groups. The right cut-off point will produce the appropriate number of clusters, and separate the data well based on attribute similarities.

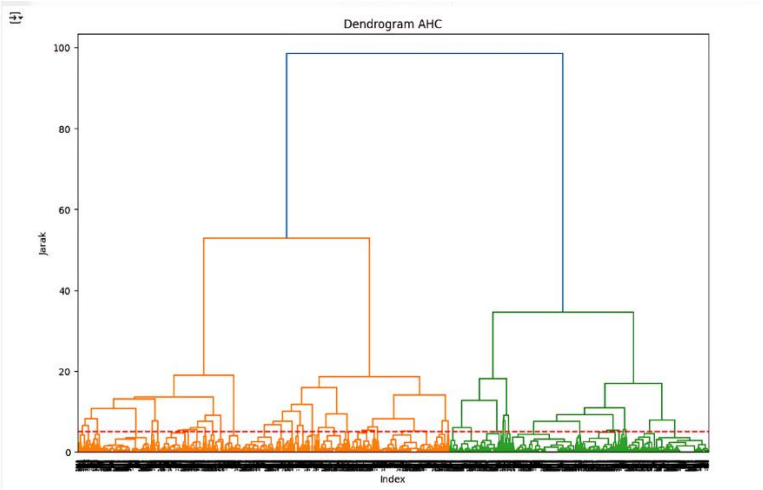

Fig. 7 Distance Test Results with Dendrogram

The test results using the silhouette coefficient from the best number of clusters are shown by the Silhouette value which is getting closer to 1. The results obtained from the cluster value between the K-Means and AHC algorithms using the silhouette coefficient is illustrated in Figure 8.

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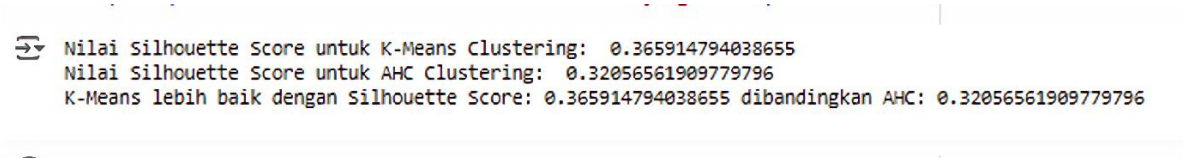

Fig. 8 Silhouette Score Results

Based on analysis conducted , value **Silhouette Score** for K-Means Clustering is **0.3659** , while mark **Silhouette Score** for Agglomerative Hierarchical Clustering (AHC) is **0.3206** . A higher Silhouette Score value high on K-Means shows that algorithm This give formation of more clusters Good compared to with AHC.

Silhouette Score values range from between -1 to 1, where values nearing 1 signify that the data has good and separate clusters with clear , and value approaching 0 indicates that the data is on the border between two clusters. In case here , K-Means shows better clustering performance well , so can concluded that K-Means is better effective in grouping student data based on the assessment given , compared with AHC method .

This result can become consideration important for taking decision in election proper clustering method for future data analysis

CONCLUSION

The results of the discussion of the grouping of teacher performance value data using the K-Means clustering and AHC methods show that based on the results of the teacher performance data cluster using the teacher performance assessment dataset in one year, cluster 0 is 531 teachers, cluster 1 is 786 teachers, and cluster 2 is 627 teachers. The results of the teacher performance assessment data cluster using the AHC method, cluster 1 is 797 teachers, cluster 2 is 645 teachers, and cluster 3 is 502 teachers. The test results using the silhouette coefficient value **Silhouette Score** for K-Means Clustering is **0.3659** , while mark **Silhouette Score** for Agglomerative Hierarchical Clustering (AHC) is **0.3206** . A higher Silhouette Score value high on K-Means shows that algorithm This give formation of more clusters Good compared to with AHC.

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