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Application of Book Clustering Based on Borrowing Frequency Using K-Means at PBD Aviation Vocational School

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Abstract

The rapid advancement of science and technology has enabled the application of data mining techniques in various domains, including education and library management. At PBD Aviation Vocational School, managing the library collection presents a major challenge due to the large number of students and the diverse frequency of book borrowing, leading to inefficiencies in procurement and maintenance. This study aims to develop a data-driven system for clustering books based on borrowing frequency using the K-Means algorithm to optimize collection management. The research was conducted using a quantitative approach, where library borrowing data were processed through the K-Means clustering method integrated into a web-based system. The algorithm classified books into three categories: frequently borrowed, quite frequently borrowed, and rarely borrowed. The results showed that the implementation of the K-Means algorithm effectively identified borrowing patterns, enabling the library to make more accurate decisions regarding book procurement, maintenance, and collection renewal. Furthermore, the web-based interface facilitated faster access and real-time visualization of borrowing trends, improving operational efficiency and data-driven decision-making. The findings highlight the importance of integrating data mining methods in educational library systems to enhance resource utilization and service quality, supporting evidence-based management in the digital transformation era.

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1. Introduction

The rapid advancement of science and technology has played a transformative role across multiple domains, especially within information systems and data analysis. Among these developments, data mining emerges as a pivotal discipline enabling the extraction of meaningful patterns and insights from large and complex datasets. In recent years, scholars have applied data mining techniques in diverse fields such as finance, healthcare, education, and library and information science, tailoring methods like clustering, classification, association rules, and predictive modelling to suit specific research needs (Ma & Lund, 2021; Rafieinasab et al., 2023). Within the realm of educational institutions, the integration of data mining has become increasingly prominent: as libraries and learning resource

centres accumulate growing volumes of user-interaction and borrowing data, the potential to leverage that information for enhanced decision-making becomes more apparent (Pang, 2022; Wang et al., 2023). Consequently, school libraries—which serve as central hubs of student engagement with reading and knowledge acquisition—can benefit substantially from applying such methods. The burgeoning volume of digital and physical circulation data necessitates efficient analytical frameworks that extend beyond traditional manual monitoring. By embedding data mining into library operations, institutions can not only track usage more effectively, but also anticipate user needs, optimise resource allocation, and adapt to changing literacy demands. Thus, the convergence of technological progress and data-driven insights offers a promising foundation for innovation in library management—a foundation that supports institutions in transitioning from reactive maintenance to proactive strategic planning in meeting students' learning and literacy requirements.

School libraries fulfil a foundational role in supporting the learning process by offering access to a diverse collection of books and learning materials, fostering students' literacy, engagement, and knowledge growth. At the PBD Aviation Vocational School, for instance, the library forms an essential component of the educational ecosystem, providing reading resources that complement classroom instruction and self-directed study. With approximately 560 active students engaged in learning activities, the vari-ety and frequency of book borrowings are considerable. This scale not only reflects high demand for library services but also complicates administrative tasks related to monitoring usage patterns and managing collections effectively. The heterogeneity of student reading interests, borrowing behaviours, and resource turnaround presents a demanding context for library administrators who aim to ensure that the collection remains current, accessible, and aligned with student needs. As student populations grow and diversify, the library's role expands from simply lending books to acting as an intelligent resource hub that can anticipate trends and respond to emerging literacy demands. Without adequate analytical support, library staff may struggle to identify which materials are resonating with students, which remain under-utilised, and how to optimise the acquisition, retention, or removal of materials. Accordingly, a stronger focus on systematic monitoring and analysis of borrowing behaviours is essential to optimise the library's contribution to the learning environment, enabling more informed decisions around stock management, user engagement, and resource planning.

The principal problem encountered by the library at PBD Aviation Vocational School lies in the limited ability to accurately discern and classify book-borrowing patterns amidst a large and varied student population. The sheer number of students and the diversity of their reading behaviours make it difficult to pinpoint which titles are being borrowed frequently, those with moderate usage, and those rarely or never borrowed. This lack of clarity inhibits the library's capacity to make informed decisions regarding collection development, purchase of new titles, scheduling of maintenance or replacement of high-use books, and the removal or repurposing of seldom-used materials. When borrowing trends remain obscure, accumulation of rarely utilised books can occur, shelving space may be less efficiently deployed, and potential demand may go unmet. Moreover, procurement strategies may fail to match actual student interests, resulting in mismatches between supply and demand. Library personnel may therefore find themselves making decisions based on intuition or tradition rather than empirical evidence. In such a scenario, inefficiencies proliferate: high-demand books may experience wear or unavailability, under-used books occupy valuable shelf space, and opportunities for optimising the collection to support literacy and learning outcomes may be missed. Identifying and addressing these usage inequalities is thus critical for enhancing library operations, improving user satisfaction, and aligning resources with student reading behaviour.

To address these identified challenges, the employment of data mining techniques and clustering algorithms offers a promising solution for gaining actionable insights. In particular, the K-Means algorithm—a widely-used unsupervised machine-learning method—can categorise books into groups based on similarity of borrowing frequency or other relevant usage metrics. By applying K-Means, books can be grouped into three clusters—such as C1 (frequently borrowed), C2 (moderately borrowed), and C3 (rarely borrowed)—thereby enabling clearer understanding of usage patterns. The

implementation of such clustering within a web-based system further enhances accessibility and responsiveness: library staff can access the analysis in real-time, visualise trends, and generate dashboards to support strategic decision-making. Prior research in library information management has demonstrated that integrating data mining with clustering algorithms can improve the speed and accuracy of book recommendation, usage tracking, and collection optimisation (Pang, 2022; Wang et al., 2023). With a system that automates clustering and visualises output, library managers can quickly identify high-demand titles that may merit additional copies or replacement, monitor moderate-use materials for maintenance scheduling, and flag low-use items for reconsideration or removal. As a result, resource deployment becomes more evidence-based, responsive, and aligned with student reading behaviours, shifting the library from a static repository into a dynamic, data-informed service.

The development of a web-based book clustering application utilizing the K-Means algorithm at PBD Aviation Vocational School is expected to yield multiple benefits for library management, student services, and organisational efficiency. By automating the clustering of borrowing data, the system relieves staff from manual monitoring and analysis—thus reducing time-consumption, human error, and reliance on subjective judgement. Instead, decisions around procurement, maintenance, shelving, and even student engagement can be grounded in robust usage data. The anticipated outcomes include better alignment of new book acquisitions with student demand, improved scheduling of maintenance or replacement of heavily borrowed items, and reduction of dormant materials occupying shelf space without contributing to student learning. Additionally, the system can enhance transparency, enabling librarians and school administrators to monitor trends, generate reports, and respond proactively to shifts in reading behaviour. From a broader perspective, this research contributes to the literature by demonstrating how data mining and clustering techniques can be effectively applied in a school-library context—a domain that has received less attention compared to academic libraries (Ma & Lund, 2021; Rafieinasab et al., 2023). Ultimately, the study aims to optimise resource utilisation, support students' literacy and knowledge growth, and promote smarter management practices in the era of digital transformation, thereby positioning the library as a strategic partner in educational success.

2. Research Methodolgy

A method is a systematic way to address a problem. This research will go through several stages. The stages used in this study are as follows:

A. Data Collection

Conducting research requires several methods to collect the necessary data. The data collection techniques are:

a. Interviews
   This technique involves direct face-to-face meetings with relevant parties to obtain clarification on previously unclear issues, such as book borrowing at PBD Aviation Vocational School, and to ensure the accuracy of the data collected.
b. Observations
   Conducting direct observations at the location of the object of discussion at PBD Aviation Vocational School.
c. Library Research
   Library research refers to all efforts undertaken by researchers to gather information relevant to the topic or problem being studied. This information can be obtained from books, scientific papers, theses, and dissertations conducted at PBD Aviation Vocational School.

B Research Methods

This research method utilizes analytical techniques and problem clustering to address issues related to the author's thesis. The steps taken to achieve the design objectives are shown in Figure 1 below:

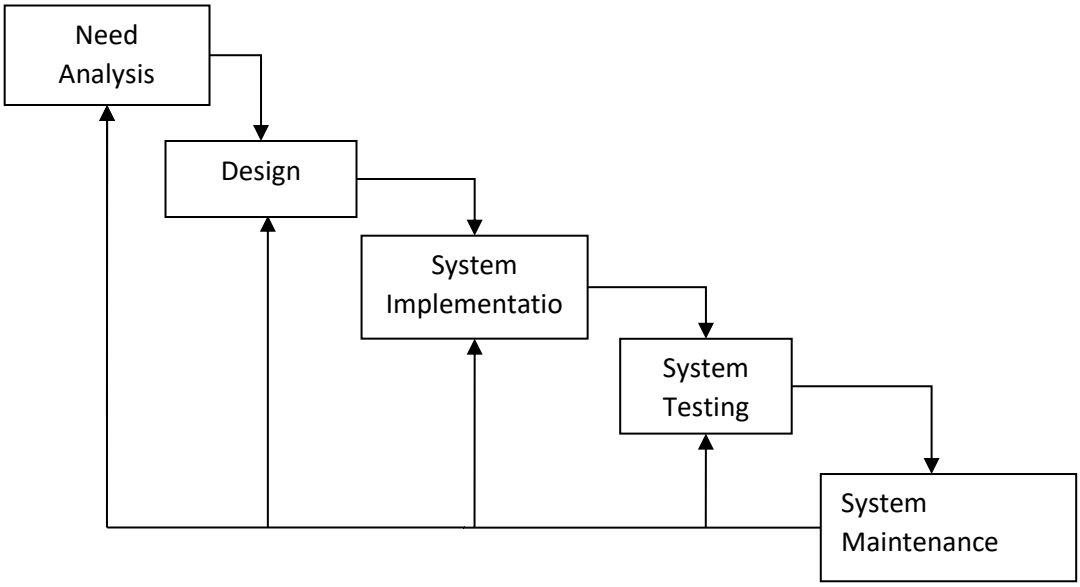

Figure 1. Waterfall Framework

Description:
1. Needs Analysis

This stage analyzes the existing system based on the data, specifically data for determining book loan clustering at PBD Aviation Vocational School.

2. System Design

This stage uses UML to design the proposed book loan clustering system at PBD Aviation Vocational School. The researcher used UML diagrams in the design, which are not merely diagrams but also provide context.

3. System Implementation

This stage translates data or solves software problems designed in a predetermined programming language. During the coding stage, it is implemented in the programming language used to build the system using PHP and MySQL.

4. Program Testing

In this stage, the researcher tests the system using theoretical and practical testing. The researcher uses blackbox testing for theoretical testing, and localhost for practical testing.

5. System Maintenance

Once the program testing is complete and running as expected, the program will display a web-based application for the program created, such as the book lending clustering at PBD Aviation Vocational School.

3. Results and Discussion

The PBD Aviation Vocational School Library is one of the facilities provided as a place for students at the PBD Aviation Vocational School. Many book titles are available at the PBD Aviation Vocational School Library, but their management is considered to be still not optimal. Because for some books, the ratio of the number of books available to the number of borrowers is not balanced, so it is possible that there will be vacancies if the number of copies is not increased. Indeed, so far the PBD Aviation Vocational School Library management has never proposed procurement or increased copies due to limited space availability. On the other hand, new books or additional copies come from donations, so

the Library management cannot manage or control which book titles should be increased. As a result, some book titles that should not be increased because of few enthusiasts actually have too many copies. Regarding increasing copies, in the future the Library management plans to reproduce itself so that the Library management must know which books are most in demand, quite in demand, and little in demand in order to determine which books should be increased.

The following are the manual calculation steps for the Book Classification Application Based on Borrowing Frequency Using K-Means at PBD Aviation Vocational School. The implementation of the K-Means algorithm requires several steps. The table below shows the manual calculation for grouping book borrowing data using K-Means for 40 borrowing records.

Table 1. Book Borrowing Data

No	Book title	Number of Loan Transactions	Number of Members Borrowing	Number of Copies	Loan Period (days)
1	Dasar Penerbangan	58	35	4	10
2	Aerodinamika Lanjut	66	14	8	6
3	Bahasa Inggris Penerbangan	43	22	3	7
4	Elektronika Dasar	60	30	3	6
5	Panduan Navigasi Udara	40	33	8	8
6	Etika Profesi	62	42	7	9
7	Struktur Pesawat	10	8	6	7
8	Matematika Terapan	70	11	5	10
9	Komunikasi Radio	16	9	3	6
10	Sejarah Penerbangan Dunia	58	24	4	6
11	Manajemen Bandara	39	34	5	6
12	Bahasa Inggris Dasar	64	43	10	5
13	Aerodinamika Dasar	13	13	5	10
14	Sistem Avionik	23	11	8	6
15	Pemrograman Dasar	41	25	9	8
16	Buku Panduan Praktikum	69	39	4	10
17	Sistem Hidrolik Pesawat	27	17	7	10
18	Bahasa Indonesia	33	24	5	5
19	Mekanika Fluida	57	52	6	7
20	Elektronika Digital	60	36	6	8
21	Pendidikan Pancasila	16	10	8	9
22	Praktikum Sistem Bahan Bakar	67	14	4	10
23	Komputer dan Jaringan	54	16	3	7
24	Bahasa Inggris untuk Aviasi	50	10	3	6
25	Manajemen Waktu	35	35	9	8
26	Matematika Lanjutan	60	19	9	5
27	Pemeliharaan Mesin	56	52	4	7
28	Fisika Penerbangan	65	26	7	10
29	Dasar Logika dan Algoritma	30	14	8	5
30	Kesehatan dan Keselamatan	61	36	5	5
31	Buku Panduan Aerodrome	34	8	6	7
32	Praktikum Elektronika	29	15	8	8
33	Bahasa Inggris Lanjutan	13	8	3	5
34	Pengantar Robotika	31	14	4	8
35	Teknologi Drone	16	15	7	6
36	Pendidikan Karakter	50	43	4	9
37	Pemrograman Python	17	17	10	9
38	Statistika Dasar	50	44	4	7
39	Sistem Otomasi Industri	20	9	5	8
40	Buku Saku Penerbangan	60	53	5	9

Thus, the initial centroid value obtained is as follows:

Table 2. Initial Centroid

Iterasi 1	Number of Loan Transactions	Number of Members Borrowing	Number of Copies	Loan Period (days)
C1(Often borrowed)	60	36	6	8
C2 (Borrowed Quite Often)	43	22	3	7
C3 (A little borrowed)	29	15	8	8

Table 3 above is the process of determining the centroid value for the iteration process until the K-Means calculation process can be carried out for each cluster center consisting of frequently borrowed, quite frequently borrowed and slightly borrowed.

ITERASI 1

Pusat *Cluster* — Jarak Objek ke *Centroid*

1. C1 N11

$$= \sqrt{(58-60)^2 + (35-36)^2 + (4-6)^2 + (10-8)^2} = 3.61$$

C2 N12

$$= \sqrt{(58-43)^2 + (35-22)^2 + (4-3)^2 + (10-7)^2} = 20.10$$

C3 N13

$$= \sqrt{(58-29)^2 + (35-15)^2 + (4-8)^2 + (10-8)^2} = 35.51$$

2. C1 N11

$$= \sqrt{(66-60)^2 + (14-36)^2 + (8-6)^2 + (6-8)^2} = 22.98$$

C2 N12

$$= \sqrt{(66-43)^2 + (14-22)^2 + (8-3)^2 + (6-7)^2} = 24.88$$

C3 N13

$$= \sqrt{(66-29)^2 + (14-15)^2 + (8-8)^2 + (6-8)^2} = 37.07$$

And so on, the results of iteration I are as follows:

Table 3. Results of Iteration I

No	Name Book	C1	C2	C3	Distance	Cluster
1	Dasar Penerbangan	3,61	20,10	35,51	3,61	C1
2	Aerodinamika Lanjut	22,98	24,88	37,07	22,98	C1
3	Bahasa Inggris Penerbangan	22,25	0,00	16,46	0,00	C2
4	Elektronika Dasar	7,00	18,81	34,86	7,00	C1
5	Panduan Navigasi Udara	20,32	12,49	21,10	12,49	C2
6	Etika Profesi	6,48	27,95	42,66	6,48	C1
7	Struktur Pesawat	57,31	35,97	20,37	20,37	C3
8	Matematika Terapan	27,02	29,38	41,35	27,02	C1
9	Komunikasi Radio	51,75	29,98	15,30	15,30	C3
10	Sejarah Penerbangan Dunia	12,49	15,20	30,69	12,49	C1
11	Manajemen Bandara	21,21	12,85	21,77	12,85	C2
12	Bahasa Inggris Dasar	9,49	30,58	44,97	9,49	C1
13	Aerodinamika Dasar	52,37	31,53	16,52	16,52	C3
14	Sistem Avionik	44,74	23,39	7,48	7,48	C3
15	Pemrograman Dasar	22,16	7,07	15,65	7,07	C2

After all data is placed into the closest cluster, the new cluster center is recalculated based on the average of the members in that cluster to obtain a new centroid calculation result that will be used for the next iteration. Cluster 1 contains 5 data, cluster 2 contains 13 data, and cluster 3 contains 22 data. After obtaining the cluster results in iteration 1, the centroid value will be found for iteration 2.

Table 4. Initial Centroid

Iterasi 2	Number of Loan Transactions	Number of Members Borrowing	Number of Copies	Loan Period (days)
C1(Often borrowed)	60,72	34,06	5,50	7,72
C2 (Borrowed Quite Often)	41,88	24,88	5,63	6,88
C3 (A little borrowed)	21,07	12,00	6,29	7,43

Table 4 shows the process of determining centroid values for the iteration process, allowing for the K-Means calculation for each cluster center, consisting of frequently borrowed, fairly frequently borrowed, and rarely borrowed.

Distance calculation for ITERATION 2

Pusat *Cluster* Jarak Objek ke *Centroid*

1. C1 N11

$$= \sqrt{(58 - 60.72)^2 + (35 - 34.06)^2 + (4 - 5.50)^2 + (10 - 7.72)^2} = 3.97$$

C2 N12

$$= \sqrt{(58 - 41.88)^2 + (35 - 24.88)^2 + (4 - 5.63)^2 + (10 - 6.88)^2} = 19.36$$

C3 N13

$$= \sqrt{(58 - 21.07)^2 + (35 - 12)^2 + (4 - 6.29)^2 + (10 - 7.43)^2} = 43.64$$

2. C1 N11

$$= \sqrt{(66 - 60.72)^2 + (14 - 34.06)^2 + (8 - 5.50)^2 + (6 - 7.72)^2} = 20.96$$

C2 N12

$$= \sqrt{(66 - 41.88)^2 + (14 - 24.88)^2 + (8 - 5.63)^2 + (6 - 6.88)^2} = 26.58$$

C3 N13

$$= \sqrt{(66 - 21.07)^2 + (14 - 12)^2 + (8 - 6.29)^2 + (6 - 7.43)^2} = 45.03$$

And so on, the results of iteration II are as follows:

Table 5. Results of Iteration II

No	Name Book	C1	C2	C3	Distance	Cluster
1	Dasar Penerbangan	3,97	19,36	43,64	3,97	C1
2	Aerodinamika Lanjut	20,96	26,58	45,03	20,96	C1
3	Bahasa Inggris Penerbangan	21,59	4,05	24,33	4,05	C2
4	Elektronika Dasar	5,12	19,04	43,04	5,12	C1
5	Panduan Navigasi Udara	20,90	8,74	28,33	8,74	C2
6	Etika Profesi	8,28	26,55	50,78	8,28	C1
7	Struktur Pesawat	57,03	36,07	11,78	11,78	C3
8	Matematika Terapan	24,96	31,52	49,02	24,96	C1
9	Komunikasi Radio	51,35	30,48	6,90	6,90	C3

No	Name Book	C1	C2	C3	Distance	Cluster
10	Sejarah Penerbangan Dunia	10,66	16,25	38,92	10,66	C1
11	Manajemen Bandara	21,80	9,63	28,45	9,63	C2
12	Bahasa Inggris Dasar	10,88	28,99	53,14	10,88	C1
13	Aerodinamika Dasar	52,21	31,38	8,63	8,63	C3
14	Sistem Avionik	44,31	23,56	3,11	3,11	C3
15	Pemrograman Dasar	21,98	3,67	23,95	3,67	C2

The following are the results of the average values taken in iteration II, which can be seen below:

Table 6. Initial Centroid

Iterasi 3	Number of Loan Transactions	Number of Members Borrowing	Number of Copies	Loan Period (days)
C1(Often borrowed)	60,72	34,06	5,50	7,72
C2 (Borrowed Quite Often)	41,88	24,88	5,63	6,88
C3 (A little borrowed)	21,07	12,00	6,29	7,43

Calculation of object distance values for the ITERATION 3 process

Pusat Cluster **Jarak Objek ke Centroid**

1. C1 **N11**

$$= \sqrt{(58 - 60.72)^2 + (35 - 34.06)^2 + (4 - 5.50)^2 + (10 - 7.72)^2} = 4.22$$

C2 **N12**

$$= \sqrt{(58 - 41.88)^2 + (35 - 24.88)^2 + (4 - 5.63)^2 + (10 - 6.88)^2} = 19.36$$

C3 **N13**

$$= \sqrt{(58 - 21.07)^2 + (35 - 12)^2 + (4 - 6.29)^2 + (10 - 7.43)^2} = 46.64$$

2. C1 **N11**

$$= \sqrt{(66 - 60.72)^2 + (14 - 34.06)^2 + (8 - 5.50)^2 + (6 - 7.72)^2} = 86.51$$

C2 **N12**

$$= \sqrt{(66 - 41.88)^2 + (14 - 24.88)^2 + (8 - 5.63)^2 + (6 - 6.88)^2} = 26.58$$

C3 **N13**

$$= \sqrt{(66 - 21.07)^2 + (14 - 12)^2 + (8 - 6.29)^2 + (6 - 7.43)^2} = 45.03$$

The results of iteration III are as follows:

Table 7. Results of Iteration III

No	Nama Buku	C1	C2	C3	Jarak	Cluster
1	Dasar Penerbangan	4,22	19,36	43,64	4,22	C1
2	Aerodinamika Lanjut	86,51	26,58	45,03	26,58	C2
3	Bahasa Inggris Penerbangan	28,07	4,05	24,33	4,05	C2
4	Elektronika Dasar	17,48	19,04	43,04	17,48	C1
5	Panduan Navigasi Udara	20,74	8,74	28,33	8,74	C2
6	Etika Profesi	15,28	26,55	50,78	15,28	C1
7	Struktur Pesawat	51,59	36,07	11,78	11,78	C3
8	Matematika Terapan	27,85	31,52	49,02	27,85	C1
9	Komunikasi Radio	116,78	30,48	6,90	6,90	C3
10	Sejarah Penerbangan Dunia	26,12	16,25	38,92	16,25	C2
11	Manajemen Bandara	21,72	9,63	28,45	9,63	C2
12	Bahasa Inggris Dasar	109,62	28,99	53,14	28,99	C2
13	Aerodinamika Dasar	53,41	31,38	8,63	8,63	C3
14	Sistem Avionik	106,19	23,56	3,11	3,11	C3
15	Pemrograman Dasar	21,60	3,67	23,95	3,67	C2

Thus, it can be seen that the clustering results are as follows:

Table 8. Frequently Borrowed Clustering Results

No	Name
1	Dasar Penerbangan
2	Elektronika Dasar
3	Etika Profesi
4	Bahasa Inggris Dasar
5	Buku Panduan Praktikum
6	Mekanika Fluida
7	Elektronika Digital
8	Pemeliharaan Mesin
9	Kesehatan dan Keselamatan
10	Pendidikan Karakter
11	Statistika Dasar
12	Buku Saku Penerbangan

Table 9. Clustering Results of Quite Frequently Borrowed Items

No	Name
1	Aerodinamika Lanjut
2	Bahasa Inggris Penerbangan
3	Panduan Navigasi Udara
4	Matematika Terapan
5	Sejarah Penerbangan Dunia
6	Manajemen Bandara
7	Pemrograman Dasar
8	Praktikum Sistem Bahan Bakar
9	Komputer dan Jaringan
10	Bahasa Inggris untuk Aviasi
11	Manajemen Waktu
12	Matematika Lanjutan
13	Fisika Penerbangan

Table 10. Slightly Borrowed Clustering Results

No	Name
1	Struktur Pesawat
2	Komunikasi Radio
3	Aerodinamika Dasar
4	Sistem Avionik
5	Sistem Hidrolik Pesawat
6	Bahasa Indonesia
7	Dasar Logika dan Algoritma
8	Buku Panduan Aerodrome
9	Praktikum Elektronika
10	Bahasa Inggris Lanjutan
11	Pengantar Robotika
12	Teknologi Drone
13	Pemrograman Python
14	Sistem Otomasi Industri
15	Dasar Logika dan Algoritma

Discussion

The clustering results generated by the implementation of the K-Means algorithm provide a clear and systematic understanding of book borrowing behavior in the PBD Aviation Vocational School

Library. Based on the results of the three iterations, the algorithm successfully grouped the data into three meaningful clusters: frequently borrowed, quite frequently borrowed, and rarely borrowed. This categorization provides valuable insight into the actual patterns of library resource utilization. Books in the frequently borrowed cluster, such as Dasar Penerbangan, Elektronika Dasar, and Etika Profesi, indicate high student demand, suggesting that these materials are essential to learning activities and should be prioritized for additional copies or preservation measures. Conversely, books in the rarely borrowed cluster, such as Sistem Avionik and Teknologi Drone, demonstrate limited engagement, indicating that these materials either lack relevance to current curricula or have insufficient promotion among students. The presence of these disparities confirms the library's initial assumption that book circulation is uneven and that management decisions must be data-driven. By applying data mining techniques, particularly K-Means clustering, the library gains the capability to transform raw transactional data into actionable information, thereby improving collection management efficiency and supporting evidence-based decision-making in procurement and maintenance planning.

From a broader academic perspective, these findings affirm the effectiveness of K-Means clustering as a decision-support tool in educational resource management. The clustering outcomes enable the library to identify dominant trends and patterns that were previously obscured by manual observation. The frequently borrowed cluster highlights the materials that align closely with student learning needs, whereas the rarely borrowed cluster identifies underutilized assets that may need review or replacement. This data-driven approach aligns with the principles of modern library management and digital transformation, emphasizing efficiency, sustainability, and responsiveness to user needs. Moreover, the implementation of a web-based system for this analysis ensures scalability and accessibility, allowing library staff to monitor changes in borrowing trends in real-time. In practice, this system not only enhances operational effectiveness but also contributes to a culture of continuous improvement within the institution, ensuring that the library remains an adaptive, student-centered, and analytically informed component of the school's learning ecosystem.

4. Conclusion

The implementation of the K-Means clustering algorithm in the PBD Aviation Vocational School Library has demonstrated its capability to provide a robust analytical framework for understanding borrowing behavior and optimizing collection management. Through systematic data processing and iterative computation, the algorithm successfully categorized books into three distinct clusters—frequently borrowed, quite frequently borrowed, and rarely borrowed—thereby revealing clear usage patterns that were previously inaccessible through manual monitoring. These results validate that data mining methods, when integrated within a web-based system, can transform traditional library operations into data-driven decision environments. The findings further underscore the importance of aligning library resource allocation with empirical evidence, ensuring that procurement, maintenance, and weeding processes are guided by actual user behavior rather than assumptions. Consequently, this research not only contributes to the operational enhancement of school libraries but also extends theoretical and practical understanding of how clustering techniques can be effectively leveraged within educational institutions to promote efficiency, accessibility, and resource sustainability. In light of these findings, several recommendations are proposed to enhance future practice and research. First, the PBD Aviation Vocational School Library is encouraged to institutionalize the use of the web-based K-Means clustering system as part of its continuous monitoring and evaluation process, ensuring that data updates are performed regularly to reflect evolving user demands. Second, expanding the scope of analysis by integrating additional variables—such as book categories, student grade levels, or academic performance—may yield deeper insights into the correlation between reading habits and learning outcomes. Moreover, future researchers should explore the comparative performance of alternative clustering methods, such as Hierarchical Clustering or DBSCAN, to evaluate efficiency and accuracy across varying data scales. Finally, the integration of predictive analytics and recommendation systems could further advance library management toward a proactive model that anticipates user preferences and dynamically adjusts collection strategies. Collectively, these steps will strengthen the role of data-

driven intelligence in educational library management, positioning school libraries as adaptive, evidence-based institutions in the era of digital transformation.

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