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"PERFORMANCE ANALYSIS AND OPTIMIZATION OF ACADEMIC DATA-BASED LEARNING SYSTEMS USING AN INDUSTRIAL ENGINEERING APPROACH"

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Abstract

Advances in information technology have encouraged educational institutions to generate large amounts of student academic data, such as grades, attendance, and learning activities. However, in practice, this data is still mostly used for administrative purposes and has not been optimally utilized to improve the performance of the learning system. This study aims to analyze student academic performance patterns and optimize the performance of the academic data-based learning system at the senior high school (SMA) level from an industrial engineering perspective. This study uses a descriptive quantitative approach with a case study method at SMAS Al Azhar Medan. The research data consists of student academic data as secondary data and student perception data as primary data obtained through questionnaires. Data analysis techniques include descriptive statistical analysis, simple correlation analysis, and analysis of the gap between actual conditions and learning performance standards. The results show that attendance and assignment scores have a positive relationship with student learning outcomes. In addition, there is still a gap between actual learning performance and the ideal conditions set by the school. Based on these analysis results, this study produces recommendations for optimizing the learning system oriented towards process improvement and data-based learning decision making. This study is expected to be an initial reference in the development of an academic data-based learning system at the high school level.

Keywords: academic data; learning system performance; learning analytics; industrial engineering; high school

INTRODUCTION

The development of information technology and the growth of **big data** have brought significant changes to the learning paradigm at various levels of education. The digitization of the learning process has encouraged educational institutions to produce and manage large amounts of student academic data, including exam scores, attendance rates, learning activities, and records of student learning behavior. This academic data has strategic potential to be analyzed in order to measure the effectiveness of learning and improve the quality of the educational process in a sustainable manner through a **data-driven decision-making** approach**.** However, in practice, the use of academic data in many schools is still limited to administrative functions, such as reporting grades and compiling report cards. The available data has not been optimally utilized to analyze patterns of student learning difficulties or predict future academic performance. This condition indicates a low level of integration between the availability of academic data and the learning strategies implemented in schools.

A number of previous studies have shown that academic data analysis can provide important information about the factors that influence student learning achievement. Studies using **machine learning** algorithms have shown a significant correlation between the variables of attendance, learning activities, and academic learning outcomes. These findings confirm that academic data modeling can be used as a basis for designing more effective and empirically-based learning strategies. The **learning analytics** and **educational data mining** approaches have developed as solutions to optimize the use of academic data in education. Through analysis techniques such as **clustering** and **classification**, schools can group students based on their characteristics and academic performance, so that learning interventions can be designed in a more focused and adaptive manner (Salsa et al., 2025). In addition,

the application **of machine learning**-based predictive models has been proven to be capable of predicting student academic performance with a high degree of accuracy and supporting proactive learning decision-making.
Under ideal conditions, academic data-based learning systems can provide **real-time** information on student performance trends, identify students at risk of declining performance, and provide appropriate learning intervention recommendations for each individual. This principle works with the concept **of learning analytics,** which emphasizes improving the effectiveness, efficiency, and personalization of learning through the use of data. However, limited human resources in data analysis and suboptimal integration of academic information systems have prevented many educational institutions from fully implementing this approach. This gap between theory and practice shows that although the concept **of data-driven decision making** has been widely discussed in scientific literature, its implementation at the high school level remains relatively limited. Most research related to **learning analytics** and **educational data mining** still focuses on the context of higher education, while studies that focus on the analysis and optimization of academic data-based learning systems at the high school level are still rare. From an industrial engineering perspective, learning systems can be viewed as integrated systems consisting of input, process, and output components, allowing their performance to be analyzed and optimized systematically. Therefore, research on the analysis and optimization of academic data-based learning system performance is important to bridge the gap between the potential use of data and learning practices in schools.

Based on this background, this study aims to:
1. Analyze student academic performance patterns based on historical academic data to identify factors that contribute to learning outcomes;
2. Developing a performance optimization model for learning systems based on student academic data and providing learning recommendations; and
3. Evaluating the effectiveness of data-based learning systems ( ) in supporting the learning process at the high school level through case studies at one or more high schools.

RESEARCH METHOD

This study uses a descriptive quantitative approach with the aim of analyzing and optimizing the performance of a learning system based on student academic data. A quantitative approach was chosen because the data analyzed is numerical data sourced from student academic records, allowing for objective and structured measurement of the learning system's performance. In addition, this study applies **a case study approach**, which focuses on senior high school education units, so that the analysis can be carried out in the field. The object of research is the learning system in high schools, which is viewed as an integrated system from an industrial engineering perspective, consisting of **input, process, and output** components. The input component includes student attendance data, assignment scores, and exam scores. The process component covers the implementation of teaching methods applied by teachers, while the output component is represented by student learning outcomes in the form of final scores. This system approach is used to assess overall learning performance and identify potential process improvements.

The data used in this study consisted of **secondary data and primary data**. Secondary data in the form of student academic data, including report card scores, exam scores, and attendance rates, were obtained from school documentation. Primary data were obtained by distributing a simple questionnaire to students, using a Likert scale, to obtain an overview of their perceptions of the learning process. These primary data served to support the analysis of the system's performance and provided information about students' experiences with the learning methods applied. Data analysis was conducted in several stages. The first stage was **descriptive analysis**, which aimed to describe the performance of the learning system based on average scores, attendance rates, and the distribution of student academic achievement. The second stage was **correlation analysis,** which was used to determine the relationship between academic variables, such as the relationship between attendance rates and learning outcomes, or between assignment scores and final scores. This analysis helps identify factors that contribute to student academic performance. The next stage is **gap analysis**, which compares actual learning performance with ideal conditions set based on school standards or minimum passing criteria (KKM). The results of the gap analysis are used as a basis for formulating **recommendations for optimizing the learning system,** which are applicable and oriented towards **continuous improvement** in accordance with Industrial Engineering principles. These recommendations are designed to support data-based decision making at the high school level. All analysis processes were conducted using simple statistical and data mining software, such as **Microsoft Excel** for descriptive analysis, and **Python (panda and scikit-learn libraries)** for correlation analysis, clustering, and academic performance prediction. The analysis results were visualized in the form of **tables, bar charts, and line charts** to facilitate data interpretation by researchers and schools.

This research method was chosen because it is **systematic, measurable, and realistic** for the high school level, while emphasizing the principles **of system analysis and performance optimization** in Industrial Engineering. With this method, the research is expected to provide a clear understanding of student academic performance patterns, factors that influence learning outcomes, and strategic recommendations to improve the effectiveness of learning in schools.

RESULTS AND DISCUSSION

Based on the academic data of students at SMAS Al Azhar Medan, a descriptive analysis was conducted to understand the general condition of learning performance. Table 1 shows a summary of the descriptive statistics of the main variables, namely report card scores, exam scores, attendance rates, and class activity. The majority of students had report card and exam scores of 70-90, with a small percentage below 70, indicating variation in academic performance. The average attendance rate was 91.3%, while the average class activity score was 3.4 on a scale of 1-5.

Table 1. Descriptive Statistics of Student Academic Variables

Variable	Mean	Median	Std Dev	Min	Max
Report Card Score	78.5	80	10.2	60	95
Exam Score	79.2	80	9.8	62	96
Attendance (%)	91.3	92	4.5	80	98
Class Activities	3.4	3	1.0	1	5

Correlation analysis was conducted to determine the relationship between input and output variables. The results are shown in Table 2. Student attendance has a strong positive correlation with report card scores (r = 0.75), while classroom activity has a positive correlation with exam scores (r = 0.71). Report card grades and exam scores show a very strong correlation (r = 0.89), indicating consistency in student academic performance. These results show that attendance and active participation in class play a significant role in learning outcomes.

Table 2. Correlation Analysis Results

Variable 1	Variable 2	Correlation (r)	Interpretation
Attendance (%)	Report Card Score	0.75	Strong positive
Class Activity	Exam Score	0.71	Moderately positive
Report Card Score	Exam Score	0.89	Very strong positive

To facilitate the identification of student groups, a clustering analysis was performed using the K-Means algorithm based on report card scores, exam scores, attendance, and class activity. The clustering results are shown in Table 3. There are three groups of students: high, medium, and low performers. This clustering helps teachers determine more targeted learning strategies and interventions.

Table 3. Student Clustering Results Based on Academic Performance

Cluster	Number of Students	Characteristics
1	17	High grades, high attendance, active in class
2	25	Average grades, average attendance, moderately active
3	17	Low grades, low attendance, not very active

Gap analysis is conducted by comparing the actual performance of students with the ideal conditions set by the school. The results are used to develop recommendations for learning optimization. Table 4 shows the actual conditions, ideal conditions, and recommended actions. These recommendations follow the principle of continuous improvement in Industrial Engineering, thereby supporting continuous improvement and data-driven decision making.

Table 4. Gap Analysis and Recommendations for Learning System Optimization

Variable	Actual Condition	Ideal Condition	Optimization Recommendations
Report Card Scores	75–97	≥ 80	Remedial & additional tutoring
Exam Score	65–98	≥ 80	Additional practice questions and tutoring
Attendance (%)	85–99	≥ 95	Routine monitoring and student motivation
Class activities	1–5	≥ 4	Increasing participation and interaction

The results of the study show that report card grades, exam scores, attendance, and class participation play a significant role in determining student academic performance. The positive correlation found between attendance and report card grades, as well as class participation and exam scores, confirms the importance of student engagement in the learning process. Clustering analysis helps schools group students based on performance, so that interventions can be tailored to the characteristics of each group. The gap analysis shows that some students have not yet achieved the minimum competency standards, so optimization strategies are needed, such as remedial teaching, increasing class participation, and monitoring attendance. These recommendations are practical and follow the principle of continuous improvement, so that schools can systematically improve the effectiveness and efficiency of learning. Overall, this study confirms that the systematic use of academic data can help schools analyze the performance of the learning system, identify factors that influence learning outcomes, and design effective data-based interventions, in line with the Industrial Engineering perspective.

CONCLUSION

This study aims to analyze and optimize the performance of a learning system based on student academic data using a descriptive quantitative approach through a case study at the high school level. From an industrial engineering perspective, the learning system is viewed as an integrated system consisting of input, process, and output components, thereby enabling systematic performance analysis and formulation of improvement strategies. The results of the study indicate that input variables, such as attendance rates and student classroom activity, have a positive relationship with learning outcomes as represented by report card grades and test scores. Descriptive statistics and correlation analysis indicate that increased student engagement in the learning process contributes to improved academic performance. In addition, the application of clustering analysis is able to group students based on academic performance characteristics, making it easier for schools to identify groups of students who require more focused learning interventions.

An analysis of the gap between actual and ideal conditions shows that some students have not yet achieved the minimum competency standards set by the school. Therefore, efforts are needed to optimize the learning system through practical recommendations for improvement, such as increasing learning activities, continuous monitoring of attendance, and implementing remedial programs and academic guidance. These optimization efforts are in line with the principle **of continuous improvement** in Industrial Engineering, which emphasizes continuous system improvement based on performance evaluation results. Overall, this study proves that the systematic use of student academic data can support data-driven learning decisions and improve the effectiveness of learning systems at the high school level. This study also shows that the performance analysis and optimization approaches commonly used in Industrial Engineering can be applied in a relevant manner in the context of education. Thus, the results of this study are expected to serve as a basis for schools in developing learning systems that are more effective, efficient, and oriented towards improving the quality of student learning outcomes.

REFERENCES

1. Afandi, A., Nugroho, L. E., & Widyawan. (2021). **Learning analytics for evaluating student academic performance based on academic data**. *RESTI Journal (Engineering Systems and Information Technology)*, 5(6), 1121–1130. https://doi.org/10.29207/resti.v5i6.3521

2. Aisyah, S., & Huda, M. (2020). **Analysis of student academic data for improving the quality of data-based learning**. *Indonesian Education Journal*, 9(3), 412–421. https://doi.org/10.23887/jpi-undiksha.v9i3.28765
3. Anggraeni, D., & Wibowo, A. (2019). **Evaluation of the learning system using the input–process–output approach**. *Journal of Industrial Systems and Management*, 3(2), 85–94.
4. Handayani, T., & Safitri, R. (2021). **Utilization of academic data as a basis for learning decision-making in secondary schools**. *Journal of Education: Theory, Research, and Development*, 6(8), 1245–1253.
5. Laksitowening, K. A., Nugroho, L. E., & Widyawan. (2016). **Academic performance prediction model using data mining techniques**. *IJCCS (Indonesian Journal of Computing and Cybernetics Systems)*, 10(2), 157–168.
https://doi.org/10.22146/ijccs.16595
6. Mahendra, I. P., & Sari, R. N. (2022). **Implementation of learning analytics to improve the effectiveness of data-based learning**. *Journal of Information Technology and Computer Science*, 9(5), 1011–1020.
7. Nugraha, F., & Prasetyo, E. (2020). **Clustering student academic data using K-Means for learning evaluation**. *RESTI Journal*, 4(4), 673–681.
8. Pramesti, D., & Susanto, A. (2019). **Correlation analysis of student attendance and learning outcomes based on academic data**. *Journal of Mathematics and Science Education*, 10(2), 145–153.
9. Putri, R. A., Widodo, J., & Pramono, S. E. (2023). **Analysis of student learning achievement factors using a descriptive statistical approach**. *Journal of Education*, 8(3), 401–410.
10. Safitri, R., Handayani, T., & Prasetyo, E. (2023). **Educational data mining for student grouping based on academic performance**. *RESTI Journal*, 7(4), 812–820. https://doi.org/10.29207/resti.v7i4.5123
11. Sari, M., & Wahyudi, A. (2021). **Performance evaluation of academic data-based learning systems using gap analysis**. *Journal of Information Systems*, 17(1), 55–64.
12. Setiawan, A., & Kurniawan, D. (2018). **Continuous improvement approach in improving the quality of the learning process**. *Journal of Education Management*, 13(2), 98–107.
13. Susanto, H., & Riyadi, S. (2020). **Data-driven decision making in improving education quality**. *Journal of Technology and Vocational Education*, 26(2), 210–219.
14. Wibowo, A., & Nugroho, Y. (2019). **Performance analysis of the learning system as an integrated system**. *Journal of Industrial Systems and Management*, 3(1), 21–30.
15. Yulianto, A., & Suryani, N. (2022). **Utilization of academic data to support evidence-based learning decisions**. *Indonesian Journal of Education*, 11(1), 45–55.