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Web-Based Gradient Boosting Machine Implementation for Student Success Data Classification at Muhammadiyah Elementary School in East Medan

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A B S T R A C T

The rapid advancement of data-driven education has enabled schools to utilize machine learning to identify factors influencing student success. This study presents the development and implementation of a web-based Gradient Boosting Machine (GBM) model for classifying student success data at Muhammadiyah Elementary School in East Medan. The proposed system aims to assist educators in evaluating student performance through predictive analytics that integrates academic, behavioral, and attendance data. The research methodology includes data preprocessing, feature selection, and model training using the GBM algorithm due to its robustness in handling non-linear relationships and reducing classification errors through iterative boosting. The web-based application is designed with an interactive interface, allowing teachers and administrators to input, analyze, and visualize student performance patterns easily. The evaluation results indicate that the GBM model achieves high classification accuracy, outperforming traditional algorithms such as Decision Tree and Logistic Regression. This system not only provides accurate predictions of student performance levels but also generates actionable insights for improving learning outcomes and academic interventions. The research contributes to the integration of machine learning and educational management by demonstrating how predictive modeling can be operationalized in real-time through a web-based platform to support data-informed decision-making in Muhammadiyah schools.

INTRODUCTION

Primary education is a fundamental stage in the education system, forming the foundation of students' knowledge, skills, and character. Success at this level significantly determines the quality of education at subsequent levels. Primary school education plays a crucial role in building students' cognitive and affective foundations and preparing them for the more complex stages of secondary education (Susilahati et al., 2023). However, one crucial phase often faced by students is the transition from primary school (SD) to junior high school (SMP), which is fraught with challenges both academically and emotionally. Students' readiness for higher education depends heavily on effective guidance during the primary school years [1,2].

This problem arises from the lack of a technology-based system that can automatically analyze and classify students' likelihood of success in public junior high school selection. The manual management of academic and non-academic data limits schools' ability to conduct rapid and accurate evaluations. This presents a challenge because the available data must first be manually processed, which is time-consuming and labor-intensive, and prone to error [3,4,5].

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The Gradient Boosting Machine was chosen for its ability to handle complex data and produce accurate classifications. Previous studies have shown that the Gradient Boosting Machine (GBM) has the advantage of providing more optimal results compared to other classification algorithms.

Research by [6,7] demonstrated that the Gradient Boosting Machine (GBM) is effective in classifying telemarketing success, with an accuracy of 90.39%, demonstrating the algorithm's ability to handle large data sets with high accuracy. Furthermore, research by [8,9] demonstrated that the Gradient Boosting Machine (GBM) produces good accuracy in classifying chili quality based on images, with precision, recall, and F-Score values of around 69.7%, indicating its effectiveness in processing varied and complex data.

This solution will be implemented by building a web-based application that integrates a Gradient Boosting Machine to analyze and classify student data. This application will process data consisting of report card grades, attendance rates, and other academic and non-academic achievements. The existing historical data will be used to train the GBM model, and once the model is trained, the web-based application will automatically classify whether or not a student is likely to be accepted into a public junior high school.

By implementing a web-based system using a Gradient Boosting Machine, schools are expected to obtain an accurate classification of student success in the public junior high school selection process. This will enable schools to identify students who require special attention early, allowing them to receive appropriate and tailored guidance.

METHOD

Data Pre-Processing

The collected data is not used directly in the model. Prior to this, several data processing steps are performed, including data cleaning, handling missing values, and converting categorical data to a numeric format using encoding techniques. Furthermore, the data is normalized to ensure that the numeric features have the same scale.

Dataset Separation

The cleaned dataset is then divided into two separate parts:

a. Training Data (80%): The largest portion of the data used to "train" or "teach" the Gradient Boosting Machine (GBM) algorithm to recognize patterns of student success.
b. Test Data (20%): A smaller portion that the model never sees during training. This data is used later to test how well the model performs on new data, ensuring a fair and objective evaluation.

Gradient Boosting Machine Model Training

Once the data is ready, the GBM algorithm is used to model the data. GBM is an ensemble learning technique that combines several simple models to form a more robust model. The model is trained using the training data, and model parameters are adjusted using hyperparameter tuning techniques.

Evaluate and Save the Model

The trained model is tested using test data to measure accuracy and classification performance. Evaluation is performed using metrics such as accuracy, precision, recall, and F1-score to ensure the model can provide accurate and reliable classifications. If the results are satisfactory, the "smart" model is saved in .pkl or .joblib file format. This allows the model to be reused in applications without the need for retraining from scratch.

RESULTS AND DISCUSSION

Manual Calculation of Gradient Boosting Machine

This sub-chapter explains the process of selecting a data subset to be used as a case study for manual calculations. This subset selection aims to simplify the calculation process for ease of use while remaining representative of the entire dataset. From a total of 40 available student data sets, 10 were purposively selected for the simulation. This selection was based on representativeness of the target class, with 5 students having the status "Accepted" (Status = 1) and 5 students having the status "Not Accepted" (Status = 0). This criterion ensures that the calculation process can illustrate how the learning model distinguishes between the two classes equally. In addition to class balance, the selected data subset also contains significant variation in values for each attribute. For example, the Achievement_Score ranges from 0 to 40, and the Average_Report_Score ranges from 85.5 to 95.0. This variation is essential to demonstrate how the decision tree, as a weak learner in GBM, is able to identify meaningful split points for separating the data. If the data used is too homogeneous, the algorithm learning process will be less illustrative. The data subset used is presented in Table 1.

Table 1. Data Subset for Manual Calculation

ID	Average Report Card Score	Achievement Score	Attendance Percentage	Status (y)
1	92.5	30	98	1
2	88.0	0	95	0
3	90.2	10	97	1
4	85.5	0	92	0
5	95.0	40	99	1
6	89.0	5	94	0
7	91.5	20	96	1
8	86.2	0	90	0
9	93.8	25	97	1
10	87.5	0	93	0

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The first step in GBM is to create a uniform initial prediction for all observations. For classification problems, this initial prediction is expressed not as a probability, but as a value in log-odds space. This approach is the mathematical foundation of GBM for classification. GBM additively builds a model on a log-odds scale, where each subsequent decision tree increases or decreases this value. The log-odds scale allows for unlimited model updates between 0 and 1, making it mathematically more stable and flexible. Probabilities are the end result of the transformation, not the basic unit of the learning process.

Login Page Display

This page serves as the main gateway to access the classification system. Users, such as school administrators, must enter a valid username and password to access the system. The page is designed simply, with a focus on security and ease of access. On the right side, there's a welcome message and a brief explanation of the system's primary function: identifying student potential using data.

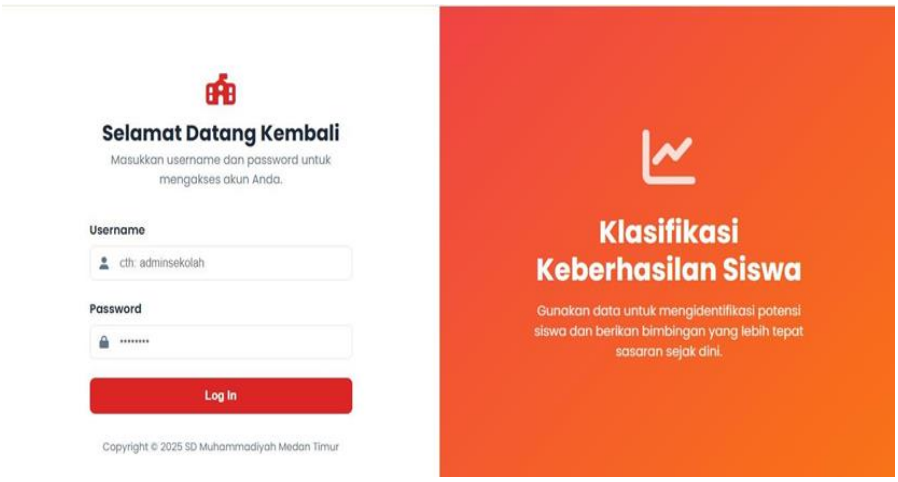

Figure 1. Login Page View

Dashboard Page View

The Dashboard is the first page users see after successfully logging in. It presents a visual summary of key information through statistical panels, such as Total Students, Number of Models Trained, and Last Classification Status. There's also a blank area that will display a graph of the latest prediction results once classification data is available. The main navigation menu is located on the left side, providing easy access to all system features such as Manage Data, Train & Test Models, and more.

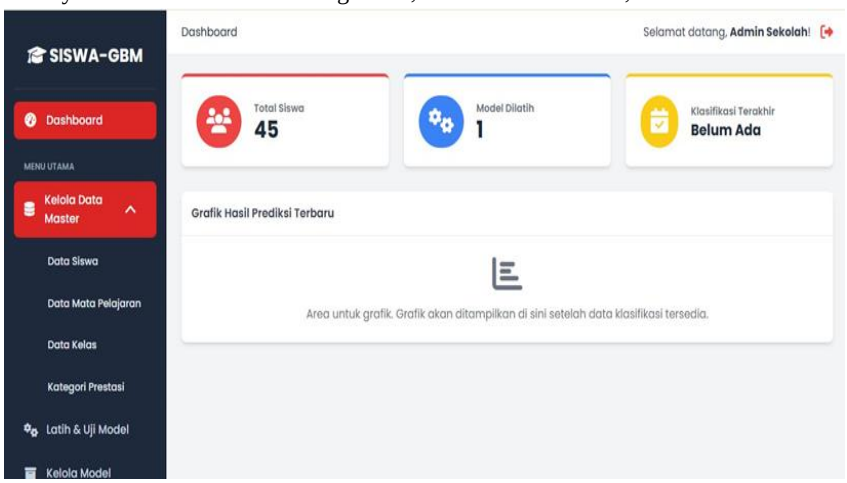

Figure 2. Dashboard Page View

Student Data Management Page Display

This page serves as a central point for student data management. Admins can view a complete list of students along with key information such as name, grade point average, achievement score, and graduation status. A search feature allows for quick student retrieval and allows for adjusting the amount of data displayed per page. Each row of student data is accompanied by action buttons ("Input Training Data" and "Edit") that allow admins to update information or incorporate student data into the model's training dataset.

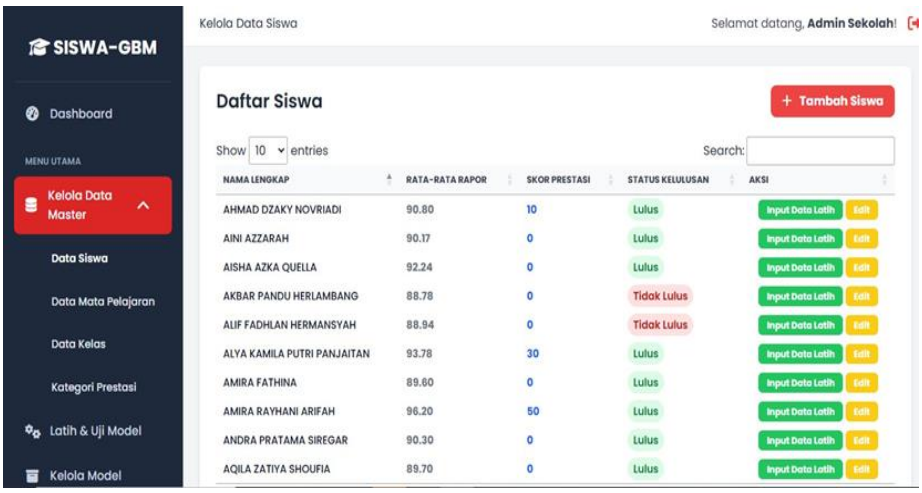

Figure 3. Manage Student Data Page View

Display the Add Student Data Page

This page provides a form for adding new student data to the system. Admins can fill in detailed student information, including Full Name, Place of Birth, Student ID Number (NIS/NISN), Date of Birth, Class, Gender, and Address. This form is designed to ensure complete data required for analysis and classification. Once all fields are filled in, the data can be saved to the database by clicking the "Save Student Data" button.

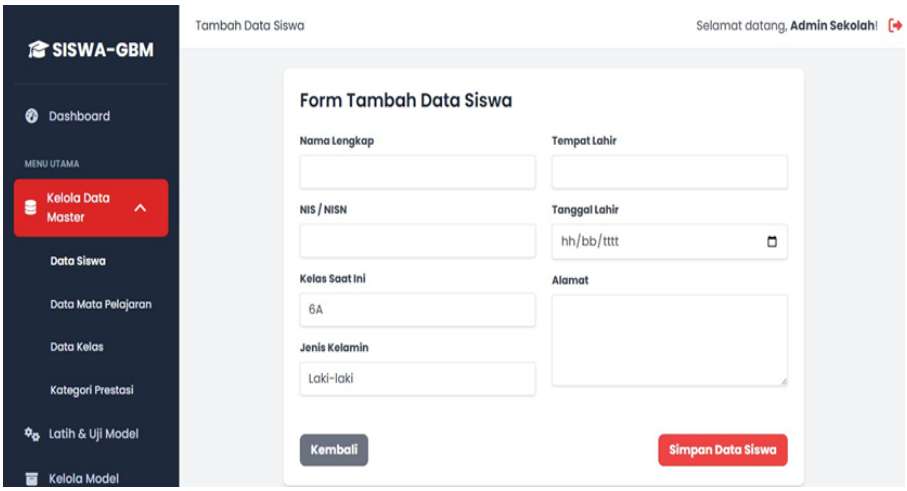

Figure 4. Add Student Data Page View

View the Manage Subject Data Page

This page allows admins to manage the list of subjects available at the school. The information displayed includes the subject name and a brief description. This page features a search feature to make it easier for admins to find specific subjects. For each subject, there are "Edit" and "Delete" action buttons, giving admins the flexibility to update or delete data according to curriculum requirements.

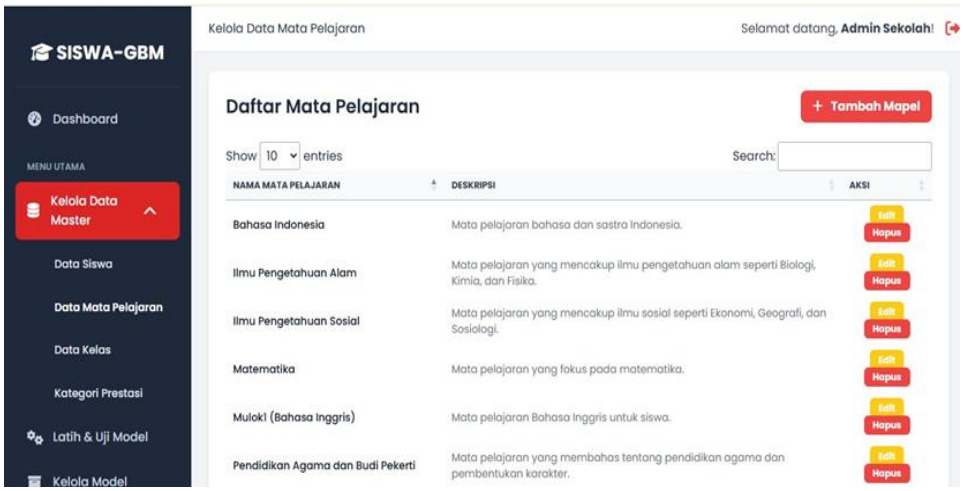

Figure 5. Subject Data Management View

Add Subject Data Page Display

This page is the form used to add new subjects to the system. Admins need to enter the subject name and a brief description of the subject. Once the information is filled in, the admin can save it by clicking the "Save Data" button. This page is important for keeping the subject list in the system relevant to the applicable curriculum.

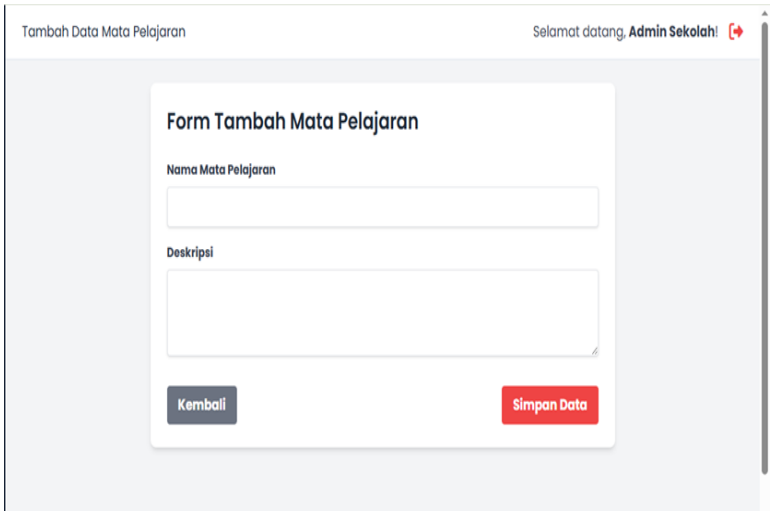

Figure 6. Add Subject Data Display

Manage Class Data Page View

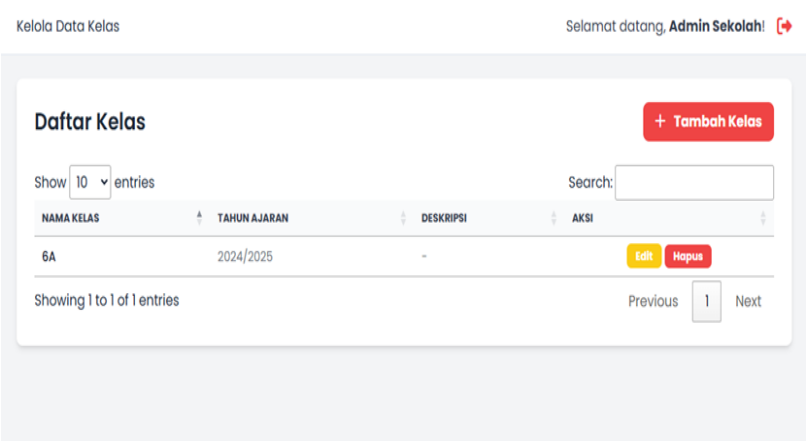

Figure 7. Manage Class Data View

Add Class Data Page Display

This page is used to manage class data within the school. In tabular form, this page displays information such as Class Name, Academic Year, and Description. Admins can easily view active classes for a given academic year. Each class record has "Edit" and "Delete" action buttons for updating or deleting class data as needed.

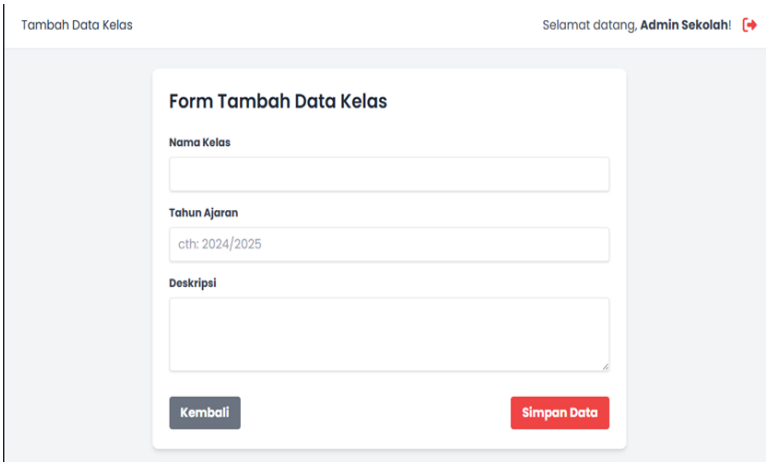

Figure 8. Add Class Data Page View

Manage Achievement Categories Page View

The Manage Achievement Categories page serves as a central management hub for various student achievements and their scores. Admins can view a complete list of existing achievements, such as "1st Place in Class" or "1st Place in Science National Science Olympiad," along with their respective levels (e.g., School, District, National) and points scored. This page features a search feature for easy management and "Edit" and "Delete" action buttons for each category, allowing admins to flexibly update or delete achievement data.

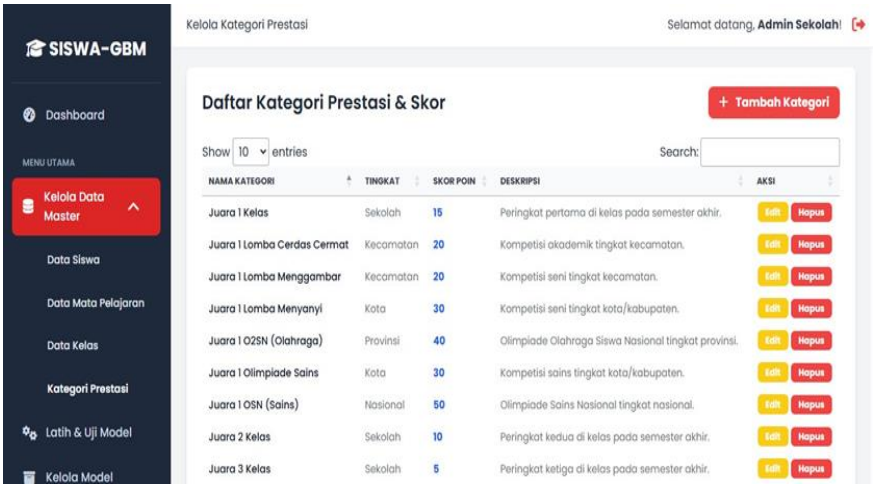

Figure 9. Achievement Category Page View

CONCLUSION

Based on the analysis, implementation, and system testing conducted, several conclusions can be drawn that address the research problem formulation as follows: Successful Implementation of the Gradient Boosting Machine (GBM) Algorithm: The GBM algorithm was successfully implemented to classify student success data. This process proceeds through systematic stages, beginning with model initialization on a log-odds scale to generate initial probability predictions. Next, the algorithm iteratively calculates pseudo-residuals, which represent the errors from previous predictions. A simple decision tree model (weak learner) is then built to predict these errors, with the Achievement Score attribute identified as the most significant data separator. The model is then updated additively with contributions from the new tree, ultimately increasing the predicted probability closer to the actual value. The Most Influential Factor is the Achievement Score: Results from the model training process and manual calculations indicate that the Achievement Score is the most influential factor affecting student success. In the first iteration, the model was able to perfectly separate

students with "Pass" and "Fail" statuses using only this attribute. This indicates that students with a record of non-academic achievement, no matter how small, have a much higher likelihood of success than students with no achievement at all. Web-Based Classification System Successfully Built: A web-based system has been successfully built to assist schools in decision-making. This system is designed with an architecture that separates the frontend (built with PHP and HTML) and the backend (built with Python and the Flask API). This system provides complete functionality, from master data management (students, classes, subjects, achievements), interactive model training flows, to model management and classification result history.

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