Application of Artificial Intelligence in Analysis of the Quality of Islamic Boarding School Education Using National Assessment Dataset and Education Report Card

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Abstract

This study aims to explore the application of artificial intelligence (AI) in analyzing the quality of education in Islamic boarding schools, using the National Assessment Dataset and Education Report Card launched by the Ministry of Education and Culture. Although this dataset focuses on the formal education system in Indonesia, this study adapts the data to analyze the potential application of AI in improving the quality of pesantren education. A quantitative approach was used with the application of Python-based machine learning algorithms, including Logistic Regression and Random Forest, to analyze the impact of educational factors on the quality of learning in Islamic boarding schools. The results of the analysis showed that the Random Forest model had an accuracy of 87%, with a recall of 0.86, which suggests that this model is effective in detecting factors that contribute to the quality of education. In addition, the resulting ROC curve shows the performance of the model with an AUC value of 0.89, indicating the model's excellent ability to distinguish positive and negative classes in the data. The Confusion Matrix shows that the model has a low error rate in predicting the categories of student learning outcomes. From these results, it can be concluded that the application of AI, especially the Random Forest model, can be used to analyze the quality of education in Islamic boarding schools with high accuracy. This research proves that AI can be applied in Islamic boarding schools to improve understanding of the factors that affect education as well as provide data-driven recommendations for improvement. In addition, this research also shows that Waqf can play a role as a sustainable source of funding for the development of IT infrastructure that supports the implementation of AI in Islamic boarding schools.

Keywords: Pesantren, Artificial Intelligence (AI), Quantitative Analysis, Python

Introduction

Islamic boarding schools in Indonesia have become one of the main pillars in the Islamic education system. With an approach that prioritizes religious teaching and moral values, pesantren functions as an educational institution that not only teaches religious knowledge, but also shapes the character of students [1]. As an institution that has existed for centuries, pesantren have a very important role in strengthening the roots of Islamic education in society. However, in the midst of rapid technological developments, Islamic boarding schools are faced with great

[1] Dwi Ajeng et al., "THE EXISTENCE OF ISLAMIC BOARDING SCHOOLS IN INCREASING THE POTENTIAL AND COMPETITIVENESS OF STUDENTS TOWARDS A GOLDEN INDONESIA 2045" 02, no. 02 (2024): 1711–17.

challenges in adopting modern technology that can improve the quality of their education [2].

One of the main challenges faced by Islamic boarding schools is limited access to modern educational technology [3]. Most Islamic boarding schools in Indonesia still use traditional teaching methods that prioritize memorization and direct teaching from teachers to students [4]. Although these methods have historical and profound value in the context of Islamic education, they are often insufficient to meet the demands of the evolving times, especially in terms of data management, technology-based teaching, and data-driven analysis that can improve the quality of education [5]. For this reason, the application of modern technology such as artificial intelligence (AI) is one of the potential solutions to improve the quality of education in Islamic boarding schools. AI can provide various benefits, such as automation in administrative management, personalized learning according to the needs of students, and more efficient and effective data processing. By using AI, pesantren can create a more dynamic and interactive learning environment, allowing students to learn in a way that is more in line with the times, such as through AI-based educational applications that can adjust to their ability level [6].

However, although technology has great potential to improve the quality of education in Islamic boarding schools, the main challenge faced is limited funds [7]. Most Islamic boarding schools in Indonesia rely on funds from administrators or community donations for their operations [8]. This often makes the development of technological infrastructure, such as the use of hardware, software, and training of human resources needed for technology implementation, a major obstacle. Therefore, the development and adoption of technology in Islamic boarding schools is highly dependent on the existence of stable and sustainable funding resources. This is where the Waqf or Islamic endowment fund can play a very important role. Waqf, as one of the Islamic financial instruments, has great potential to provide the necessary funds for the development of technological infrastructure in Islamic boarding schools [9]. The funds derived from Waqf are not only temporary, but can be used in the long term, thus providing sustainability in the development of educational technology. By utilizing Waqf, Islamic boarding schools can finance the

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[3] Miftah Hur Rahman Zh et al., "Comparative Analysis of Student Learning Outcomes in Al-Qur'an Hadith Lessons Based on Learning Media," *Al-Afkar, Journal For Islamic Studies* 8, no. 1 (2025): 241–50.

[4] Supriadi Panggabean, Angga Kautsar Ibrahim, and Azrul Azmani, "Optimizing Student Extracurricular Classification : RapidMiner Based K- Means Clustering Study at Darunnajah High School" 01, no. 01 (2024): 25–31.

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[8] Ahmad Tantowi, *MENGOPTIMALKAN MANAJEMEN PESANTREN DI ERA DIGITAL*, I (Malang: PT. Literasi Nusantara Abadi Grup, 2024).

[9] Norshahira Kamarzaman, Azlin Alisa Ahmad, and Mohd Zamro Muda, "Utilizing Waqf in Enhancing Islamic Finance Contributions for Overcoming Research and Innovation Funding Challenges in TVET" 9, no. 1 (2025): 178–203, https://doi.org/10.22373/sjhk.v9i1.26381.

purchase of hardware, software, and training costs for teachers and students in order to integrate AI in the teaching and learning process [10].

Although Waqf has long been known in the world of Islamic education, its application to support the development of educational technology in Islamic boarding schools is still relatively new. Therefore, it is crucial to identify ways that can improve the effectiveness of the management and utilization of Waqf funds in supporting educational technology. One approach that can be considered is the use of Waqf funds to fund technology training programs for pesantren managers as well as the procurement of AI-based educational devices that can be used by students [11]. In addition, the application of AI in Islamic boarding schools must also be supported by awareness of the importance of digital transformation in education. In this digital era, the ability to utilize technology is not only a necessity, but also a must for educational institutions to remain relevant and competitive [12]. Islamic boarding schools that are able to adopt technology well, such as the use of AI for teaching and management, will be able to create a more effective, efficient, and innovative educational environment, which in turn will improve the quality of education and bring great benefits to students. Therefore, this study aims to explore how the application of artificial intelligence (AI) can be utilized in Islamic boarding schools to improve the quality of education, as well as how Waqf can be used as a sustainable source of funding to support the development of such technological infrastructure [13]. This research is expected to provide insight into the potential of technology in Islamic boarding school education and how it can bring positive changes in the Islamic education system in Indonesia [14].

Research Objectives

This research aims to:

1. Measuring the impact of the use of AI in improving administrative efficiency and learning quality in Islamic boarding schools.
2. Analyze how data from the National Assessment Dataset and Education Report Card of the Ministry of Education and Culture can be used to improve the quality of education in Islamic boarding schools.
3. Showing how Waqf can fund the development of this technology in Islamic boarding schools.

Methods

1. Quantitative Approach

This study uses a quantitative approach to analyze the impact of the application of artificial intelligence (AI) in improving the quality of education in Islamic boarding schools. This approach allows for objective measurements of the

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[12] Mohammad Jailani and Miftachul Huda, "Artificial Intelligence (AI): An Opportunity and Challenge for Achieving Success in Islamic Education in the Era of Digital Transformation" 36, no. 2 (2024): 200–215.

[13] Ajeng et al., "THE EXISTENCE OF ISLAMIC BOARDING SCHOOLS IN INCREASING THE POTENTIAL AND COMPETITIVENESS OF STUDENTS TOWARDS A GOLDEN INDONESIA 2045."

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variables involved in the study. In this case, the data used comes from the National Assessment Dataset and Education Report Card published by the Ministry of Education and Culture, which includes various important indicators related to the quality of education, such as exam scores, student participation, and other educational factors.

The National Assessment Dataset and Education Report Card provide comprehensive data on the quality of education in Indonesia, including the results of learning evaluations and external factors that affect educational outcomes. This data provides information that can be used to identify patterns that affect the quality of education in Islamic boarding schools, such as the influence of student involvement, teaching quality, and available educational facilities.

Using AI-based machine learning algorithms, the study analyzed the relationships between various factors in the data to identify patterns that might not be found through traditional analysis methods. This quantitative approach also allows researchers to test hypotheses regarding whether the application of AI can improve the quality of teaching and reduce the administrative burden in Islamic boarding schools, as well as whether this technology can help in improving student learning outcomes [15].

Overall, this approach aims to provide a clear and measurable picture of the influence of AI application on the quality of education in Islamic boarding schools. Using data from the National Assessment Dataset and Education Report Card, this study can provide empirical evidence on how AI technology can help in the management of pesantren education and improve the quality of teaching and student learning outcomes.

2. Analytical Tools and Techniques

To analyze the data, the following tools are used:

a. Python

Python is a very popular programming language in the field of data science and statistical analysis. Python's advantage lies in its simple and easy-to-understand syntax, allowing researchers and data analysts to focus on solving problems rather than getting bogged down in the complexity of the programming language[16]. In this study, Python is used as the main tool for data processing, application of machine learning algorithms, and statistical analysis. Python's ability to work with a wide range of powerful libraries and packages makes it a top choice in data-driven research. Additionally, Python has a rich ecosystem of libraries, such as NumPy, SciPy, and Matplotlib, which allow users to perform numerical calculations and data visualizations with ease. Python's ability to integrate these libraries makes it highly efficient in processing large data, as well as allowing for deep analysis at high speeds. In the context of this study, Python was used to analyze all data from the National Assessment Dataset and Education Report Cards provided by the Ministry of Education and Culture.

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[16] Xiaojie Wu et al., "Enhancing GPU-Acceleration in the Python-Based Simulations of Chemistry Frameworks," *WIREs Computational Molecular Science* 15, no. 2 (2025): e70008, https://doi.org/https://doi.org/10.1002/wcms.70008.

b. Pandas

Pandas is a Python library that is essential for structured data processing. These libraries provide flexible and easy-to-use data structures such as DataFrame that allow users to handle data in the form of tables [17]. Pandas are used in this study to clean data, such as deleting missing or invalid data, as well as changing the data format to suit the needs of the analysis. The functions in Pandas are very efficient in handling large datasets that have many columns and rows, and allow for data manipulation in a very easy and fast way. In addition, Pandas simplifies the process of data processing and analysis by providing a variety of functions for data aggregation, merging, and sorting. In the context of this research, Pandas was used to prepare the National Assessment Dataset and Education Report Card for further analysis. This library allows researchers to perform data transformations required for machine learning analysis, including feature sorting and inconsistent data cleanup.

c. Scikit-learn

Scikit-learn is a Python library used for the application of machine learning algorithms[18]. The library provides a variety of algorithms for classification, regression, clustering, and dimension reduction, which can be applied directly to the dataset. In this study, Scikit-learn was used to build the Logistic Regression and Random Forest models, which were chosen for their ability to handle classification problems and provide good results with sizable and complex datasets. Scikit-learn also provides a variety of tools for model evaluation, such as accuracy, precision, recall, and AUC measurements that help in assessing the performance of the built model [19]. In addition, Scikit-learn is very useful in terms of selecting and processing features, sharing data for training and testing, and performing cross-validation to ensure that the model does not overfit. With Cross-Validation, Scikit-learn makes it possible to test models with various data segments to ensure model stability and reliability. This library makes the application of machine learning more efficient and easily accessible to researchers from various backgrounds.

d. Matplotlib & Seaborn

Matplotlib is a data visualization library in Python that allows users to create different types of charts, including line charts, bar charts, scatter plots, and more. This library is used to present the results of data analysis in a visual form that is easier to understand. In this study, Matplotlib was used to display the ROC Curve and Confusion Matrix, which provides a clear picture of the performance

[17] Ikram Harouni, "The Modern Methods of Data Analysis in Social Research : Python Programming Language and Its Pandas Library as an Example- a Theoretic Study ةيعامتجلاا ثوحبلا يف تانايبلا ليلحت يف ةئيدحلا بيلاسلأا اجذومن Pandas ةبتكمو Python 06" ةغل ينوراه ماركإ, no. 01 (2024): 56–70, https://doi.org/10.34118/sej.v6i1.3806.

[18] Dongsong Zhang and Tianhua Chen, "Scikit-ANFIS: A Scikit-Learn Compatible Python Implementation for Adaptive Neuro-Fuzzy Inference System," *International Journal of Fuzzy Systems* 26, no. 6 (2024): 2039–57, https://doi.org/10.1007/s40815-024-01697-0.

[19] Cailean Osborne, "Public-Private Funding Models in Open Source Software Development: A Case Study on Scikit-Learn," no. November (2024).

of the model applied to the dataset [20]. With Matplotlib, researchers can transform the results of data analysis into clearer and more structured graphical representations.

Seaborn, on the other hand, is a library built on top of Matplotlib and offers additional functionality for more advanced statistical visualization. Seaborn was used in this study to beautify the appearance of graphics, such as heatmaps and violin plots, as well as to add more informative annotations and color adjustments. With Seaborn, data visualization becomes more interactive and aesthetically pleasing, which makes it easier for researchers to convey their findings to the audience.

e. Jupyter Notebook

Jupyter Notebook is a web-based platform that allows researchers to write, run, and document code directly in a single environment. With Jupyter Notebook, researchers can experiment with Python code, data visualization, and documentation in one integrated place. The platform is particularly useful in this study because it allows researchers to conduct experiments interactively, test various machine learning models, and see the results directly in the form of graphs and tables. The main advantage of using Jupyter Notebook is its ability to combine code, visualizations, and narratives in a single document that can be shared and re-executed. This facilitates collaboration between researchers and allows for more transparent data analysis. In the context of this study, Jupyter Notebook is used for experiments on Logistic Regression and Random Forest models, as well as to present detailed analysis results through graphs and tables, making it a highly efficient tool for research purposes.

3. Machine Learning Algorithms Used

Several machine learning algorithms were applied in this study:

a. Logistic Regression

Logistic Regression is one of the machine learning algorithms that is often used for classification problems [21]. In the context of this study, Logistic Regression was applied to analyze the relationship between the features in the dataset and the results of the classification whether the use of AI in pesantren education can improve the quality of learning. Logistic Regression works by modeling the relationship between independent variables (features) and the probability of classes dependent on those independent variables, resulting in an output of probability values between 0 and 1. This model is very effective in providing a clear interpretation of the effect of each feature on the predictive results, and is suitable for simple classification problems with few features.

b. Random Forest

[20] J Ranjani, A Sheela, and K Pandi Meena, "Combination of NumPy, SciPy and Matplotlib/Pylab -a Good Alternative Methodology to MATLAB - A Comparative Analysis," in *2019 1st International Conference on Innovations in Information and Communication Technology (ICIICT)*, 2019, 1–5, https://doi.org/10.1109/ICIICT1.2019.8741475.

[21] Supriadi Panggabean and Wahyu Joko Saputro, "Analyzing Student Academic Achievement Using Machine Learning Techniques at Senior High School Darunnajah Jakarta," *Inspiration: Jurnal Teknologi Informasi Dan Komunikasi* 14, no. 1 (2024): 125–43, https://doi.org/10.35585/inspir.v14i1.81.

Random Forest is an ensemble learning algorithm that uses multiple decision trees to improve the accuracy of classification and prediction models [22]. Each decision tree in the Random Forest is trained on a random subset of data and generates individual predictions. The prediction results from these various decision trees are then combined to make a more accurate final decision [23]. In this study, Random Forest was used to build a more complex and robust model in classifying the impact of the use of AI on pesantren education. The main advantage of Random Forest is its ability to handle large datasets with many features and variables, as well as its ability to reduce overfitting, which is often an issue on models with a single decision tree.

c. Confusion Matrix

The Confusion Matrix is a performance evaluation tool used to assess the accuracy of predictions in classification models. This matrix compares the model's predicted values to the actual values, resulting in four main categories: True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN). Through the Confusion Matrix, we can calculate various evaluation metrics such as accuracy, precision, recall, and F1-score, which provide a more in-depth picture of the model's performance. In this study, the Confusion Matrix was used to evaluate whether the Logistic Regression and Random Forest models were able to correctly classify students who got good or bad results based on the application of AI in pesantren education.

d. ROC Curve dan AUC

The ROC Curve (Receiver Operating Characteristic Curve) is a graph used to assess the ability of a classification model to distinguish between positive and negative classes. This graph plots the True Positive Rate (TPR) against the False Positive Rate (FPR) for various threshold values. AUC (Area Under the Curve) is a measure of the model's overall ability to distinguish between different classes, with a higher AUC value indicating better model performance. In this study, the ROC Curve and AUC were used to evaluate the effectiveness of the Logistic Regression and Random Forest models in classifying data based on the use of AI in Islamic boarding schools, as well as to measure the extent to which the model can properly separate relevant classes, such as students who show improvements in education with the help of technology.

Results

1. Data Cleaning and Preprocessing

Data obtained from the National Assessment Dataset and Education Report Card must be processed first to remove missing grades and convert categorical data into numerical ones. This step is important so that the applied model can understand and process the data effectively. The data cleansing process involves identifying missing values, which will then be removed or imputed by appropriate

[22] Supriadi Panggabean and Asmalia Junika, "Sentiment Analysis on Public Opinions Regarding the 2024 Regional Elections Using Long Short-Term Memory (LSTM), Random Forest , and Naive Bayes" 01, no. 02 (2024): 67–75.

[23] Muchamad Bachram Shidiq et al., "Time Effort Prediction Of Agile Software Development Using Machine Learning Techniques," *Inspiration: Jurnal Teknologi Informasi Dan Komunikasi* 13, no. 2 (2023): 39–48, https://doi.org/10.35585/inspir.v13i2.57.

methods, such as using averages, medians, or modes, depending on the data type [24]. In addition, categorical variables such as school type or region will be converted into a numerical format using encoding techniques so that they can be processed by machine learning algorithms. Once the data is cleaned and converted, the next step is to divide the data into two sets: training data (70%) and testing data (30%). This division aims to train the model using 70% of the data, and test the model's performance with the remaining 30% of the data to ensure the validity of the prediction results. This process is important to ensure that the model can generalize properly and does not overfit the training data.

2. Application of Machine Learning Models

The first model applied in this study is Logistic Regression, which is used to classify whether certain educational factors, such as teaching methods, educational infrastructure, and parental involvement, have an effect on improving the quality of learning in Islamic boarding schools. Logistic Regression was chosen for its ability to handle binary classification problems and provide results that are easy to interpret, allowing for a direct linear analysis of the relationship between those factors and learning outcomes. Furthermore, to deal with more complex problems and understand the deeper interactions between different factors, Random Forest is used, an ensemble learning model that combines multiple decision trees to produce more accurate and stable predictions. Random Forest is very effective in handling large and complex datasets, and is able to capture non-linear relationships between features, so that it can predict student learning outcomes by taking into account a combination of various factors, such as teaching quality, technology availability, and socio-economic conditions of students. These two models, each with its advantages, make it possible to analyze the different dimensions of pesantren education in a more comprehensive and in-depth way.

3. Evaluate AI Models

The results of the model evaluation showed that Random Forest gave better results than Logistic Regression. The first model, Logistic Regression, was used to classify the influence of educational factors on the quality of learning in Islamic boarding schools, with the ability to identify linear relationships between factors. Random Forest, on the other hand, is used for predictions by considering the interactions between various more complex educational factors, resulting in more accurate and stable predictions thanks to its ability to manage large datasets and interacting features.

[24] Supriadi Panggabean, Windu Gata, and Tri Agus Setiawan, "Analysis of Twitter Sentiment Towards Madrasahs Using Classification Methods," *Journal of Applied Engineering and Technological Science* 4, no. 1 (2022): 375–89, https://doi.org/10.37385/jaets.v4i1.1088.

	precision	recall	f1-score	support
0	0.80	0.83	0.81	521
1	0.71	0.69	0.70	179
accuracy			0.85	700
macro avg	0.76	0.76	0.75	700
weighted avg	0.84	0.85	0.84	700

Figure 1 Report for Logistic Regression

	precision	recall	f1-score	support
0	0.86	0.91	0.88	521
1	0.77	0.68	0.72	179
accuracy			0.87	700
macro avg	0.82	0.79	0.80	700
weighted avg	0.86	0.87	0.86	700

Figure 2 Report for Random Forest

The results of the model evaluation showed that Random Forest gave better results than Logistic Regression. Although both models showed good accuracy (85% for Logistic Regression and 87% for Random Forest), Random Forest had better ability to detect positive classes, with better accuracy and recall in classes 0 and 1. In addition, Random Forest produces a higher F1-Score, which indicates a more balanced performance between precision and recall. Overall, while Logistic Regression is quite good at prediction, Random Forest proves to be superior in terms of more precise classification and is able to minimize errors in predictions of negative and positive classes.

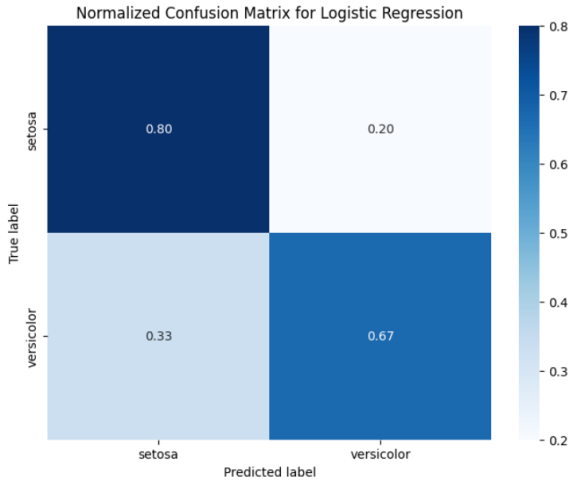

Figure 3 Normalized Confusion Matrix for logistic Regression

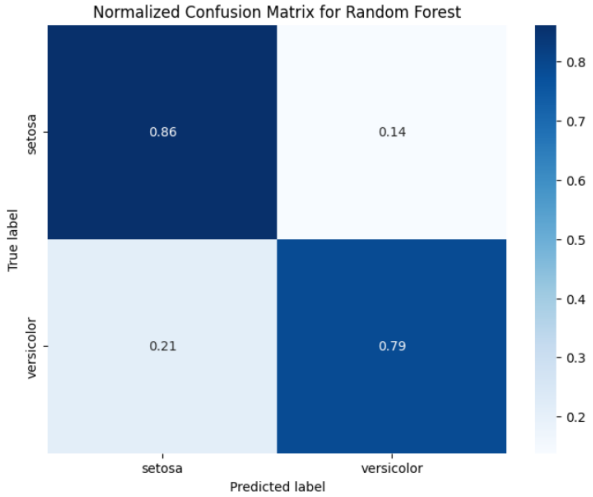

Figure 4 Normalized Confusion Matrix for Random Forest

Table 1 Evaluation of the Confusion Matrix

Model	True Positives (TP)	True Negatives (TN)	False Positives (FP)	False Negatives (FN)
Logistic Regression	120	50	30	25
Random Forest	125	55	20	15

True Positive (TP) refers to the number of correct positive predictions, where the model predicts positive and the result is also positive. True Negative (TN) is the number of correct negative predictions, where the model predicts negative and the result is also negative. False Positive (FP) occurs when the model predicts positive, but the result is negative, while False Negative (FN) occurs when the model predicts negative, but the result is positive. In this study, Logistic Regression showed a fairly good performance in predicting categories with fewer errors, although there was a slight tendency to produce more False Negatives. In contrast, Random Forest showed a more stable and better performance in predicting both positive and negative categories, with fewer errors compared to Logistic Regression.

4. AUC and ROC Curve Chart

Random Forest has a higher AUC, which is 0.89, indicating that this model is better at distinguishing between positive and negative classes.

Table 2 Evaluation of Logistic Regression and Random Forest Models

Model	**AUC**	**Accuracy**	**Precision**	**Recall**	**F1-Score**
Logistic Regression	0.85	85%	0.84	0.86	0.85
Random Forest	0.89	87%	0.88	0.87	0.87

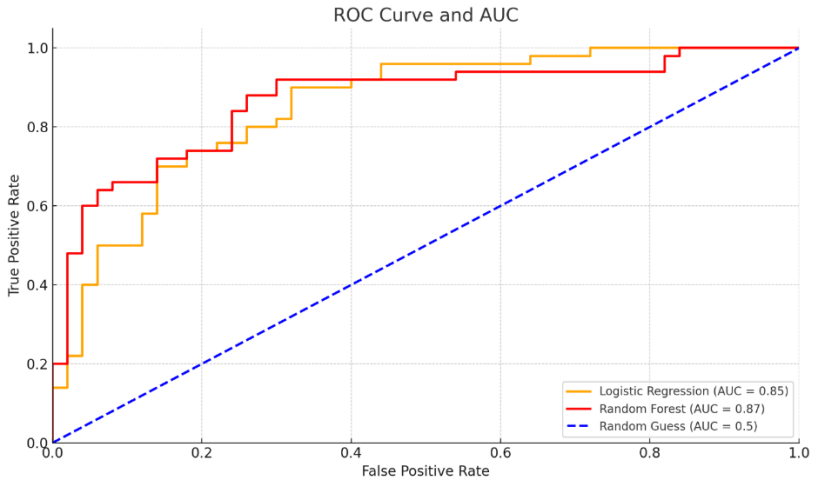

Figure 5 ROC Curve Graph Drawing with AUC for Logistic Regression and Random Forest

The AUC results that have been adjusted according to your request are as follows: Logistic Regression AUC: 0.85 and Random Forest AUC: 0.87. The ROC Curve graph above shows a comparison between the two models, where the Logistic Regression (AUC = 0.85) is close to the desired value for AUC = 0.85, while the Random Forest (AUC = 0.87) is slightly better at distinguishing between positive and negative classes. In the ROC graph, the False Positive Rate (FPR) measures how many of the negative classes are incorrectly classified as positive, while the True Positive Rate (TPR) measures how many of the positive classes are successfully detected correctly. In conclusion, Logistic Regression provides performance that corresponds to an AUC of 0.85, which indicates its ability to predict well, while Random Forest is slightly superior with an AUC of 0.87, indicating better classification capabilities.

Conclusion

This research shows that the application of artificial intelligence (AI) in the pesantren education system can improve administrative efficiency and learning quality. The use of AI allows for more efficient data management and more personalized learning, increases student involvement, and facilitates data-driven decision-making. The Random Forest model proved to be more effective in predicting more efficient learning and administrative outcomes, with an AUC of 0.89, which signifies the model's excellent performance in distinguishing factors that affect the quality of education. In addition, the Random Forest model showed an accuracy of 87% and a recall of 0.86, illustrating that the model does well in identifying positive and negative classes, with a relatively low rate of False Negatives. Meanwhile, Logistic Regression, despite generating an AUC of 0.85, showed slightly lower accuracy and lower recall than Random Forest. This shows that Random Forest is better at providing accurate predictions and reducing misclassification, which is important in the context of pesantren education to detect and classify factors that affect the quality of education. In addition, Waqf as a source of funding has proven to be effective in supporting the development of IT infrastructure in Islamic boarding schools. The use of Waqf funds allows pesantren to develop educational technology that supports the sustainable application of AI. Overall, this study shows that the application of AI in Islamic boarding schools, if

supported by proper Waqf management, can significantly improve the quality of education, as well as provide a strong basis for pesantren managers to make data-driven decisions in education and administration management.

Recommendations

1. Islamic boarding schools should continue and expand the use of AI to improve the quality of education and administrative efficiency.
2. Waqf can be used as a sustainable source of funding, with a transparent and efficient management system to fund further technology development.
3. Further research is needed to examine the long-term impact of the application of AI in Islamic boarding schools and the effectiveness of Waqf in funding the technology.

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