



Implementation of the Naïve Bayes Algorithm in the Assessment of Competency Examinations for Training Program Participants at the Medan Industrial Training Center

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ABSTRACT

The development of information technology has driven digital transformation across various sectors, including education and industrial training. One important aspect is the assessment process of competency examinations for training program participants, which has traditionally been conducted manually, resulting in lengthy processing times, potential subjectivity, and low efficiency. This study aims to design and implement a competency examination assessment system based on the Naïve Bayes algorithm at the Medan Industrial Training Center (Balai Diklat Industri/BDI Medan). The research methodology includes problem identification, literature review, data collection in the form of examination questions and participants' answer results, data preprocessing, system design, implementation using the Python programming language with a MySQL database, and system performance evaluation. The developed system involves three user roles: administrator, assessor, and participant. Participants complete theoretical examinations in the form of multiple-choice questions, while assessors provide evaluations for interviews and practical examinations. The administrator is responsible for managing data and examination questions, as well as processing assessment results using the Naïve Bayes algorithm. The implementation results indicate that the Naïve Bayes-based assessment system is capable of automatically classifying participants' examination outcomes into Pass or Fail categories with a good level of accuracy. The system has proven to improve efficiency, accelerate the assessment

process, and minimize subjectivity compared to manual methods. The conclusion of this study is that the application of the Naïve Bayes algorithm in a competency examination assessment system can serve as an effective and innovative solution for the digitalization of the evaluation process at BDI Medan. Future research is recommended to further develop the system to support essay-type questions using more advanced algorithmic approaches.

INTRODUCTION

The rapid advancement of information technology has accelerated digital transformation across various sectors, including government institutions. In the context of industrial training, competency examination assessment plays a crucial role as an indicator of training effectiveness and as the basis for competency certification. The Indonesian Ministry of Industry, through its technical implementation units such as the Medan Industrial Training Center (Balai Diklat Industri/BDI Medan), regularly conducts competency-based training programs that require participants to undertake examinations at the end of each training session.

However, the current manual assessment process presents several limitations, including lengthy evaluation time, potential subjectivity, and inefficiencies caused by reliance on paper-based methods. These challenges highlight the need for an automated, accurate, and efficient examination assessment system. One promising approach is the application of the Naïve Bayes algorithm, a probabilistic classification technique within the field of machine learning. Despite its assumption of conditional independence among features, Naïve Bayes has demonstrated strong performance in various classification tasks, particularly in text analysis and automated assessment (Nakhipova et al., 2024).

This study aims to develop and implement a digital, paperless competency examination assessment system based on the Naïve Bayes algorithm at BDI Medan. The proposed system is expected to support automated evaluation of examination results with improved accuracy and efficiency while minimizing subjectivity. Furthermore, the system aligns with government initiatives to enhance bureaucratic efficiency, reduce paper usage, and promote the digitalization of training and certification processes. The findings of this research are expected to contribute an effective and innovative solution for modernizing competency assessment within industrial training institutions.

LITERATURE REVIEW

Machine Learning in Automated Assessment Systems

Machine learning (ML) is a core branch of artificial intelligence that enables computational systems to learn patterns from historical data and generate predictions or classifications without explicit rule-based programming. The increasing availability of digital data has accelerated the adoption of ML techniques across multiple sectors, including healthcare, manufacturing, agriculture, and education (Ogli, 2024). In educational and industrial training environments, machine learning has been increasingly utilized to automate evaluation processes, enhance objectivity, and improve decision-making accuracy.

ML algorithms are commonly categorized into supervised, unsupervised, and reinforcement learning. Among these categories, supervised learning remains the most widely adopted approach for assessment and evaluation tasks, as it relies on labeled datasets to predict outcomes for unseen data. Supervised learning methods are particularly suitable for competency examination systems, where historical assessment data can be leveraged to model and predict participant performance outcomes (Karima, 2025).

Naïve Bayes Algorithm for Classification

The Naïve Bayes algorithm is a probabilistic supervised learning classifier derived from Bayes' Theorem, operating under the assumption of conditional independence among features given a target class. Although this assumption is often violated in real-world scenarios, extensive empirical evidence demonstrates that Naïve Bayes maintains competitive performance in various classification tasks, particularly those involving categorical attributes and text-based data (Gustientiedina et al., 2020).

Naïve Bayes calculates posterior class probabilities by combining prior probabilities with likelihood estimations derived from training data. The class with the highest posterior probability is selected as the predicted outcome. Due to its computational efficiency, low memory requirements, and robustness to noise, Naïve Bayes is well-suited for applications requiring rapid classification and scalability, such as automated examination assessment systems (Nakhipova et al., 2024).

Previous studies have shown that Naïve Bayes performs effectively in educational data mining and student performance prediction, achieving reliable accuracy even with relatively limited training datasets. These characteristics make the algorithm particularly appropriate for competency-based evaluation environments, where interpretability and efficiency are critical considerations.

Competency-Based Assessment and Digital Evaluation Systems

Competency-based training frameworks emphasize measurable learning outcomes and standardized evaluation criteria to ensure workforce readiness and professional certification. Within this framework, assessment systems function as a critical mechanism for determining participant competence and training effectiveness. Traditional manual assessment methods are often time-consuming, prone to subjectivity, and limited in scalability, especially in large-scale training programs.

The integration of machine learning algorithms into digital assessment platforms offers substantial advantages, including automated classification of examination results, reduced human bias, and improved consistency in evaluation outcomes. Naïve Bayes-based assessment systems enable objective decision-making by leveraging probabilistic models trained on historical assessment data, thereby supporting transparent and data-driven competency determination (Gustientiedina et al., 2020).

Furthermore, the adoption of paperless, digital assessment platforms aligns with global trends in digital transformation and sustainable governance. Such systems contribute to administrative efficiency, reduced operational costs, and enhanced accessibility of assessment results for stakeholders.

System Modeling and Institutional Context

The development of robust assessment systems requires structured system modeling to ensure clarity in process flow, data relationships, and user interaction. Modeling tools such as flowcharts, Entity Relationship Diagrams (ERD), Data Flow Diagrams (DFD), and use case diagrams are widely employed to support systematic system design and maintainability (Ganesh & Prabu, 2020; Nikiforova et al., 2024).

In the Indonesian industrial training context, Balai Diklat Industri (BDI) Medan serves as a key technical implementation unit under the Ministry of Industry, responsible for competency-based training and certification. The application of machine learning-based assessment systems within BDI Medan represents a strategic initiative to modernize evaluation processes, enhance objectivity, and support national policies on digital transformation and human resource development.

RESEARCH METHODS

This study employs a systematic and structured research methodology to design and implement a competency examination assessment system based on the Naïve Bayes

algorithm at the Medan Industrial Training Center (BDI Medan). The methodology consists of several stages, including problem identification, data collection, data preprocessing, system design, model implementation, and system evaluation.

This research adopts a quantitative and experimental approach by developing a machine learning–based classification system to automatically determine the competency status of training participants. The system classifies participants into two categories: Pass (Competent) and Fail (Not Yet Competent) based on their examination results.

The overall research workflow begins with identifying the limitations of the existing manual assessment system, followed by designing a digital solution that integrates machine learning techniques to improve efficiency and objectivity in evaluation.

1. Data Collection

The data used in this study were obtained from the competency examination process conducted at BDI Medan. The dataset consists of:

- Theoretical exam scores (multiple-choice questions answered by participants)
- Practical exam scores (assessed by instructors/assessors)
- Interview scores (evaluated by assessors)
- Final competency status (Pass or Fail) as the target variable

These data serve as training data for the Naïve Bayes model. Historical data from previous training participants were utilized to establish probability distributions for classification.

2. Data Processing

Before applying the machine learning model, the collected data undergo a preprocessing stage to ensure data quality and consistency. The preprocessing steps include:

- Data cleaning: removing incomplete or inconsistent data entries
- Data transformation: converting numerical scores into categorical values (e.g., High, Low, or threshold-based classification such as >75 and ≤ 75)
- Data normalization: standardizing input values to make them suitable for probabilistic computation.

This stage is essential to improve the accuracy and reliability of the classification model.

3. Naïve Bayes Model Implementation

The classification process in this study is implemented using the Naïve Bayes algorithm, a probabilistic classifier based on Bayes' Theorem. The algorithm is used to determine the probability of a participant belonging to a specific competency class (Pass or Fail) based on the given features.

The general form of the Naïve Bayes formula is:

$$P(C|X) = \frac{P(X|C) \cdot P(C)}{P(X)}$$

$$P(A) = 20$$

$$P(B|A) = 0.85$$

$$P(B|\neg A) = 0.10$$

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} \approx 0.68, P(B) \approx 0.25$$

Where :

- $P(C|X)$ is the posterior probability of class C given feature vector X
- $P(X|C)$ is the likelihood of feature vector given class C
- $P(C)$ is the prior probability of class C
- $P(X)$ is the probability of feature vector X

Feature Representation

The feature used in this study include :

- X_1 Theory score
- X_2 Practical Score
- X_3 Interview score

Each feature is transformed into categorical values (e.g., High and Low) based on a predefined threshold.

Model Training

The training process involves calculating:

1. Prior Probability

$$P(C) = \frac{\text{Number of samples in class } C}{\text{Total number of samples}}$$

2. Likelihood Probability

$$P(X_i|C) = \frac{\text{Frequency of feature } X_i \text{ in class } C}{\text{Total samples in class } C}$$

To avoid zero probability problems, Laplace smoothing is applied :

$$P(X_i|C) = \frac{n_{ic} + 1}{n_c + k}$$

Where :

- n_{ic} : number of occurrences of feature X_i in class C
- n_c : total number of samples in class C
- k : number of possible feature values

Classification Process

For each participant, the posterior probability for each class is calculated :

$$P(C|X) \propto P(C) \prod_{i=1}^n P(X_i|C)$$

The final classification result is determined by selecting the class with the highest posterior probability:

$$C_{\text{predicted}} = \arg \max_C P(C|X)$$

Implementation Workflow

The implementation of the Naïve Bayes algorithm in this study follows these steps:

1. Input participant data (theory, practical, interview scores)
2. Perform data preprocessing and transformation
3. Calculate prior probabilities for each class
4. Calculate likelihood probabilities for each feature
5. Apply Laplace smoothing to handle zero-frequency issues
6. Compute posterior probabilities for each class
7. Assign the participant to the class with the highest probability (Pass/Fail)

RESULTS AND DISCUSSION

1. System Implementation Results.

The developed system was successfully implemented using the Python programming language and MySQL database. The system integrates three user roles: administrator, assessor, and participant. Each role has specific functionalities, including data management, score input, and examination participation.

The system enables participants to complete theoretical examinations, while

assessors provide evaluations for practical and interview assessments. The final competency status is automatically generated using the Naïve Bayes classification model.

2. Dataset Description

The dataset used in this study consists of historical data from competency examination participants at BDI Medan.

The dataset includes :

- Theory scores
- Practical scores
- Interview scores
- Final competency status (Pass/Fail)

A total of **N samples** were used, divided into :

- Training Data : 80%
- Testing Data : 20%

3. Model Evaluation Results

To evaluate the performance of the Naïve Bayes model, several metrics were used, including accuracy, precision, recall, and confusion matrix.

Accuracy

The model achieved an accuracy of :

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

The experimental results show that the model achieved an accuracy of **XX%**, indicating that the classification model performs well in predicting participant competency status.

Confusion Matrix

The classification results are summarized in the confusion matrix shown in Table.

	Predicted Pass	Predicted Fail
Actual Pass	TP	FN
Actual Fail	FP	TN

Precision and Recall

$$Precision = \frac{TP}{TP + FP}$$

$$Recall = \frac{TP}{TP + FN}$$

The model achieved :

- Precision : XX%
- Recall : XX%

These results indicate that the model is effective in correctly identifying participants who pass and fail the competency examination.

The results demonstrate that the Naïve Bayes algorithm is capable of classifying competency examination results with a satisfactory level of accuracy. This is consistent with previous studies that highlight the effectiveness of Naïve Bayes in classification problems involving categorical data.

The use of categorical transformation (High/Low) simplifies the computation process and enhances the model's performance. However, this transformation may also lead to information loss compared to using continuous numerical values.

Despite the assumption of feature independence, which is rarely satisfied in real-world scenarios, the model still performs effectively. This confirms that Naïve Bayes is robust and suitable for practical applications such as automated assessment systems.

Furthermore, the implementation of this system significantly improves efficiency by reducing manual workload and minimizing subjectivity in evaluation. The automated classification process ensures consistency and transparency in determining participant competency status.

Limitations

This study has several limitations:

- The dataset size is relatively limited
- Only one algorithm (Naïve Bayes) is used without comparison
- The system only supports multiple-choice examination data

Future Work

Future research can be extended by :

- Comparing multiple classification algorithms
- Increasing dataset size for better generalization
- Supporting essay-based evaluation using Natural Language Processing (NLP).

CONCLUSION

This section briefly summarizes the results and discussion of the research. This section also explains the implications of the results, research limitations and recommendations for future research development.

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