Ensemble-Based Prediction Model for Enhanced Electronics Engineering Licensure Examination Results Using Student Performance Analysis

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Abstract— **This research focuses on analyzing the impact of Electronics Engineering graduates' performance in licensure examinations on the overall quality of Higher Education Institutions (HEIs). Data mining techniques, specifically classification, are employed to examine patterns within academic performance data and predict the success of graduates in licensure examinations. The findings aim to enhance the understanding of factors influencing licensure examination performance and guide institutions in improving their instructional strategies and curriculum design. The research aims to improve prediction accuracy by training and testing different models and optimizing their hyperparameters. The ensemble model emerges as the best-performing model, combining the predictions of multiple models and achieving high accuracy rates of 95.33% and 98% in the 70:30 and 80:20 data splitting ratios, respectively. This research contributes to the application of data mining techniques in educational settings, particularly in analyzing Electronics Engineering licensure examination performance. It provides valuable insights for HEIs in evaluating and enhancing their educational programs to better prepare students for professional practice.**

Keywords—classification, data mining techniques, Electronics Engineering, ensemble, Higher Education Institutions (HEIs), licensure examinations

I. Introduction

Higher education institutions (HEIs) play a critical role in equipping graduates with the necessary knowledge, skills, and experiences to succeed in today's fiercely competitive labor markets. To ensure the professional readiness of graduates, licensure examinations have become a prerequisite for practicing various professions in many countries. The performance of HEI graduates in these examinations has emerged as a vital indicator of educational quality, reflecting the effectiveness of instruction and curriculum design [1][2]. In the Philippines, licensure examinations serve as regulatory mechanisms for professional practice across different fields, and HEIs have increasingly focused on improving their graduates' performance in these examinations by implementing interventions and remediation practices [2].

The success of a higher education institution's graduates in licensing exams frequently serves as the best indicator of the quality of the education it offers. High licensure examination performance not only showcases the institution's instructional standards but also enhances its reputation and esteem. As a result, administrators continuously monitor licensure examination performance to drive school achievements and foster improvement [3]. However, the declining performance of HEIs in licensure examinations has raised national and international concerns, necessitating self-reflection and policy changes within institutions.

Data mining, a process of identifying relevant patterns within databases, coupled with established approaches and algorithms, can be leveraged to analyze historical and current data and predict future trends. By establishing predictive models based on instances with known outcomes, data mining can play a crucial role in assessing graduates' performance in licensure examinations, evaluating curriculum effectiveness, and strengthening the reputation of higher education institutions [3][4][7]. In the context of the Electronics Engineering field, where a focused, innovative, and logical mindset is essential, the performance of graduates in licensure examinations holds particular significance. The subject matter demands a deep understanding of rapidly evolving technologies and the ability to effectively apply new concepts. Additionally, the curriculum often involves complex scientific computations and analysis, presenting challenges for average students [5].

Measuring the success and quality of a higher education institution involves meeting various standards set by accrediting bodies. The performance of graduates in licensure examinations is one such standard, and data mining techniques, particularly classification, prove to be highly valuable in accomplishing this. Classification is a predictive data mining technique that leverages known outcomes to make predictions about unknown data. By employing predictive models, it becomes possible to forecast the performance of graduates in licensure examinations based on known variables [6]. Educational Data Mining (EDM), a specific application of data mining in education, enables the exploration of educational data sets to discover valid, useful, and understandable patterns related to students' academic performance. By applying pattern recognition and machine learning principles, EDM allows researchers to gain insights into the factors that contribute to licensure examination success, aiding in the continuous improvement of teaching methodologies, curriculum design, and overall educational quality [7][8].

In light of the increasing importance of licensure examination performance as an indicator of educational quality, data mining techniques, specifically classification, are employed to analyze patterns within academic performance data and predict the success of graduates in licensure

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examinations. This research aims to improve prediction accuracy by testing different models and tuning hyperparameters, as presented in [2]. The findings will enhance our understanding of the factors influencing licensure examination performance and provide valuable insights to assist higher education institutions in evaluating and improving their educational programs, particularly in relation to predicting licensure examination success. Optimizing predictive models can enhance students' preparation for professional practice and help maintain the institution's reputation as a provider of high-quality education. Furthermore, this research contributes to the existing body of knowledge on the application of data mining techniques in educational settings, specifically in the context of licensure examination performance analysis.

II. Related Works

Research [2] aimed to predict students' success on electronics engineering licensure examinations using data mining techniques, with a focus on student-related variables. The study employed various machine learning classification algorithms, with the Random Forest model achieving the highest accuracy of 92.70%. The key finding revealed a strong association between students' verbal reasoning abilities, mathematics performance, and their licensure exam results. In particular, excellent mathematical aptitude and high verbal reasoning scores were found to be important indicators of success. The study suggests that early intervention and development of verbal reasoning skills can improve students' performance on licensure exams, potentially addressing the declining national passing rate in electronics engineering licensure exams.

This paper [6] explores the application of data mining to predict the performance of non-education graduates interested in pursuing teaching. The study focuses on analyzing data from past examination batches to predict the performance of unit earners in the Board Licensure Examination for Professional Teachers. Supervised classification algorithms are employed, and three commonly used algorithms are selected for analysis. The researchers use the WEKA data mining tool and the KDD model to guide their study. They identify GCECED as the most significant attribute influencing unit earners' performance and recommend including additional demographic and academic attributes. The C4.5/J48 algorithm is suggested for its higher accuracy, and the importance of Guidance and Counseling in ECED subjects is highlighted. The study emphasizes the need for unbiased prediction results and encourages the application of performance prediction in other professional examinations.

This research [9] develops a classification model for predicting the likelihood of students passing the Licensure Examination for Teachers (LET) using various data mining algorithms. The C4.5 Decision Tree algorithm demonstrates the highest suitability, achieving an accuracy of 73.10%, F1 measure of 62.53%, and an AUC value of 0.730. This model aids in identifying students at risk of failing the LET, enabling targeted support and increased pass rates. The study reveals the impact of general education subjects and field study courses (FSC) on the LET. The selected C4.5 Decision Tree algorithm, with an accuracy above 70% and a fair AUC value of 0.7, allows for the effective implementation of the classification model. This approach prioritizes support for struggling LET students, resulting in improved pass rates and potential accreditation benefits. Future research should explore expanding the dataset, incorporating additional indicators, and developing an automated system for analyzing factors contributing to LET performance prediction.

This study [10] explores the utilization of educational data mining to improve educational practices and learning materials. It employs logistic regression to predict licensure examination performance and develops a comprehensive application offering practice reviews, lectures, review notes, and practice exams with instant feedback. The logistic regression model reveals the significance of certain courses as predictors, achieving a highly accurate result of 93.33%. Experts evaluate the web-based application positively based on specific metrics and sub-criteria from ISO 9126. The study highlights the successful design and development of the application, the effectiveness of the logistic regression model for prediction, and the overall acceptability of the web-based platform in terms of functionality, usability, and reliability.

This retrospective study [11] aimed to identify predictors of first-attempt success in the agriculturists' licensure examination among graduates of a specific college of agriculture. The study examined various non-academic and academic variables, and the binary logistic regression model revealed significant predictors of licensure examination success, including gender, degree program, overall ability rating, and performance in specific subjects. Notably, overall ability rating and performance in soil science were identified as strong predictors. The study recommended revisiting admission and retention policies, implementing interventions to increase passing rates, offering review classes and refresher courses, monitoring student performance, enhancing instruction in crop science, and providing remedial programs. Future research suggestions included exploring additional variables and investigating graduates' experiences and test-taking techniques.

This study [12] utilized the J48 algorithm to predict the performance rates of graduates in the Board Examinations for Teachers. The model was developed using data such as college entrance examination scores, subject averages, and LET performance. The J48 algorithm proved to be reliable in accurately categorizing instances and identifying predicted failures, enabling timely intervention programs to enhance student scores. The study's findings could contribute to assessing the success rates of graduates and potentially aid in the accreditation of teacher education programs.

The Table I presented compiles data from various research studies, showcasing a range of predictive models and their associated accuracy scores in the context of specific licensure examination predictions. The primary objective of this research is to elevate the accuracy of electronics engineering licensure examination predictions by conducting an empirical evaluation of different predictive models. By systematically testing and comparing various machine learning algorithms, the researchers aim to identify the most effective model, contributing to the advancement of accurate licensure examination outcome predictions, which can offer valuable insights for educational institutions and policymakers seeking to optimize students' success in these critical assessments.

TABLE I. PREDICTIVE MODELS AND THEIR ACCURACY FOR VARIOUS BOARD EXAMINATIONS

Research Study	Model	Accuracy	Board Exam
[2] Early Prediction of Electronics Engineering Licensure Examination Performance using Random Forest	Random Forest	92.70%	Electronics Engineering (ECE) Licensure Examination
[6] Predicting B.L.E.P.T. Performance of Unit Earners using Supervised Classification Algorithms	J48 Decision Tree	89.42%	Board Licensure Examination for Professional Teachers (BLEPT)
[9] Predicting Student's Board Examination Performance using Classification Algorithms	C4.5 Decision Tree	73.10%	Licensure Examination for Teachers (LET)
[10] Predictive Data Analytics Using Logistic Regression for Licensure Examination Performance	Logistic Regression	93.33%	Civil Engineering (CE) Licensure Examination
[11] Predictors of Performance in the Licensure Examination for Agriculturists (LEA) in Western Mindanao State University	Logistic Regression	80.70%	Licensure Examination for Agriculturists (LEA)
[12] J48-Based Algorithm in Predicting the Success Rate in the Board Examination	J48 Decision Tree	91.67%	Licensure Examination for Teachers (LET)

III. RESEARCH METHODS

In this study, we have adopted a systematic approach to gather and work with the data, create predictive models, and evaluate their effectiveness. These steps—data collection, data preparation, model building, and model assessment—are essential for ensuring the reliability and credibility of our research findings. This section will provide a clear explanation of how we collected and processed the data and then went on to create and assess our predictive models.

A. Dataset

The dataset used in this research is provided by Maaliw, who utilized it in his previous study [2]. The study included a sample of 500 electronics engineering graduates from SLSU who took the exams between 2014 and 2019. The selected years were chosen because they represented the use of the same curriculum, ensuring consistency in establishing a baseline.

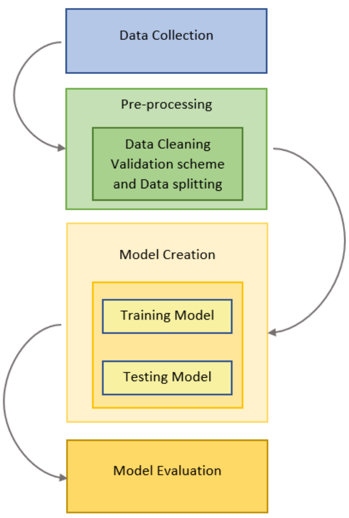

Fig. 1. Block Diagram

B. Data Preprocessing

1) Data Cleaning: Data cleaning is a crucial step in the data mining process, aimed at improving the quality and reliability of the dataset [13]. In the context of analyzing graduates' performance in licensure examinations, data cleaning involves addressing missing values, outliers, and inconsistencies. Missing values are handled by employing techniques such as imputation or excluding incomplete records based on the extent of missingness. Outliers, which can adversely impact analysis results, are identified and validated to determine their validity or erroneous nature. Inconsistencies, such as contradictory or illogical data entries, are resolved through thorough data validation and cross-referencing. Additionally, standardizing and transforming variables was performed to ensure comparability and enhance the accuracy of predictions, including scaling numerical variables, appropriate encoding of categorical variables, and applying mathematical transformations as needed. Through these data-cleaning processes, the dataset is prepared for further analysis, ensuring robust and reliable results.

2) Feature: The dataset contains math courses, professional courses, electrical circuit courses, preadmission ratings, student-related variables, and 1 target variable which is the class label (passed or did not pass).

3) Validation Scheme and Data Splitting: Both 10-fold cross-validation and the 70:30 or 80:20 data splitting ratios with Bayesian optimization were employed for the validation scheme and data splitting. The 10-fold cross-validation involved dividing the dataset into ten subsets, performing ten iterations of training and testing where each subset served as the test set once. This approach allowed for a comprehensive evaluation by utilizing different combinations of training and testing data. On the other hand, the 70:30 or 80:20 ratios divided the dataset into training and testing sets, with the majority of the data allocated for training the model and a smaller portion reserved for testing its performance. These approaches ensured robust evaluation and effective utilization of the dataset for model development and assessment.

C. Training and Testing

The dataset was split into training and testing subsets to aid in the creation and assessment of the model. The training set served the purpose of instructing the model, enabling it to grasp the data's patterns and associations. The performance of the model was then optimized using a variety of strategies and methods in accordance with the training data. Following training, the model's performance and generalizability were evaluated using data from the testing set. By evaluating the model on unseen data, it was possible to gauge its effectiveness in making accurate predictions or classifications. By conducting this training and testing process on the dataset, the researchers were able to evaluate the model's effectiveness and confirm its ability to make accurate predictions.

TABLE II. SUMMARY OF MACHINE LEARNING CLASSIFICATION MODEL RESULTS

Model	10 cross-fold validation; Bayesian Optimization			
	70:30 ratio		80:20 ratio	
	Validation Accuracy (%)	*Test Accuracy (%)*	*Validation Accuracy (%)*	*Test Accuracy (%)*
Tree (Fine Tree)	92.00	93.33	92.50	95.00
Tree (Medium Tree)	92.00	93.33	92.50	95.00
Tree (Coarse Tree)	92.57	94.67	92.25	94.00
Logistic Regression	85.71	89.33	86.25	90.00
Naïve Bayes (Gaussian Naïve Bayes)	86.00	79.33	84.50	89.00
Naïve Bayes (Kernel Naïve Bayes)	87.43	86.00	86.00	94.00
SVM (Linear SVM)	92.57	92.67	91.75	94.00
SVM (Quadratic SVM)	92.00	94.00	93.00	93.00
SVM (Cubic SVM)	91.14	94.00	91.50	92.00
SVM (Fine Gaussian SVM)	79.71	84.00	81.25	82.00
SVM (Medium Gaussian SVM)	92.00	93.33	92.50	94.00
SVM (Coarse Gaussian SVM)	84.86	86.67	85.25	92.00
Ensemble (Boosted Trees)	52.00	52.00	52.00	52.00
Ensemble (Bagged Trees)	93.43	96.67	93.75	97.00
Ensemble (RUSBoosted Trees)	83.43	96.00	90.00	96.00
Neural Network (Narrow Neural Network	89.71	92.00	91.25	89.00
Neural Network (Medium Neural Network)	89.71	92.67	90.25	93.00
Neural Network (Wide Neural Network)	89.43	92.00	91.00	92.00
Neural Network (Bilayered neural Network)	88.86	92.00	90.00	92.00
Neural Network (Trilayered Neural Network)	88.86	92.67	90.50	92.00
Kernal (SVM Kernel)	91.71	94.67	92.75	95.00
Kernel (Logistic Regression Kernel)	90.57	91.33	90.75	94.00

HYPERPARAMETER TUNING

IV. RESULTS AND DISCUSSION

Without any hyperparameter tuning, the results obtained from the cross-fold validation and different train-test ratio splits using Bayesian optimization reveal that Ensemble (Bagged Trees) and RUSBoosted Trees outperformed other models in terms of test accuracy, achieving up to 97% and 96% accuracy respectively. Tree (Fine and Medium Tree) and Kernel (SVM Kernel) also showed strong performance achieving a test accuracy of 95% in the 80:20 ratio split. Notably, Ensemble (Boosted Trees) consistently exhibited poor performance, with an accuracy of only 52% across different splits. These results emphasize the importance of selecting appropriate models and potentially exploring hyperparameter tuning to further improve the performance of the models.

The performance of various machine learning models was evaluated using two different data splitting ratios, 70:30 and 80:20, for training and testing datasets. Among the models tested, the ensemble model achieved the highest accuracy rates of 95.33% and 98% for the 70:30 and 80:20 ratios, respectively. This indicates that the combination of multiple models in an ensemble approach can effectively improve classification accuracy. The support vector machine (SVM) model also demonstrated strong performance with accuracies of 94% and 95% for the two ratios. Tree-based models, including decision trees and random forests, exhibited competitive accuracy rates of 93.33% and 95% for the 70:30 and 80:20 ratios, respectively. The Naive Bayes classifier showed a relatively lower accuracy of 82.67% for the 70:30 ratio but improved to 94% for the 80:20 ratio. Lastly, the neural network model achieved accuracies of 88% and 93% for the two ratios, showcasing its potential.

TABLE III. SUMMARY OF OPTIMIZED MODELS

Model	Accuracy %	
	70:30 ratio	*80:20 ratio*
Tree	93.33	95.00
Naive Bayes	82.67	94.00
SVM	94.00	95.00
Ensemble	95.33	**98.00**
Neural Network	88.00	93.00

Experimental Results

The ensemble model, which emerged as the best-performing model among others, utilized specific hyperparameters that contributed to its superior performance. These hyperparameters were fine-tuned to optimize the model's accuracy. The optimal combination of hyperparameters allowed the ensemble model to effectively combine the predictions of multiple trees or models, leading to enhanced accuracy. By leveraging the strengths of individual models within the ensemble, this approach successfully improved the overall predictive capability, resulting in the highest test accuracy compared to other models.

TABLE IV. HYPERPARAMETER VALUES

Hyperparameter	Value
Ensemble method	AdaBoost
Number of learners	25
Learning rate	0.3240
Maximum number of splits	7

Model Performance Visualization

The confusion matrix in fig.2 represents the results of Ensemble in 80:20 ratio using Bayesian Optimization for predicting whether individuals will pass or not pass a licensure examination. The matrix reveals that out of the 52 instances of individuals who passed the licensure examination, 51 were correctly classified as such. Similarly, out of the 48 instances of individuals who did not pass the licensure examination, 47 were correctly classified. The model demonstrates high accuracy in predicting both positive and negative outcomes, with only a single misclassification. This indicates a strong overall performance, suggesting that the model is effective in distinguishing between those who will pass and those who will not pass the licensure examination.

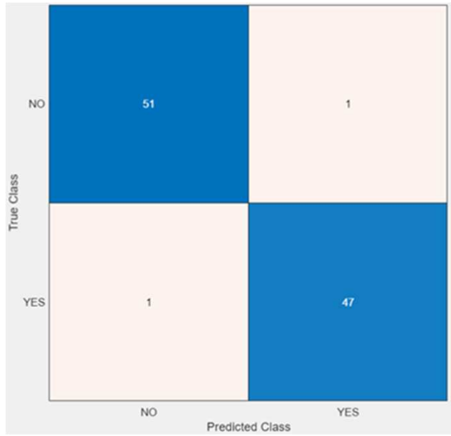

Fig. 2. Confusion Matrix of Ensemble

V. CONCLUSION

In this study, we conducted an analysis of Electronics Engineering graduates' performance in licensure examinations, utilizing data mining techniques to predict their outcomes accurately. Our extensive investigation involved the evaluation of various machine learning models, and the Ensemble model consistently emerged as the top performer, achieving impressive accuracy rates of 95.33% in the 70:30 data splitting ratio and an exceptional 98% in the 80:20 ratio. These findings emphasize the critical role of data-driven predictive models in shedding light on the factors influencing licensure examination success.

Beyond academic interest, our research carries practical significance for both higher education institutions (HEIs) and policymakers. Enhancing graduates' readiness for licensure examinations is integral to their future professional success. Equally important, it is central to maintaining the prestige and reputation of HEIs as providers of top-tier education. The ability to tailor teaching strategies and curriculum content based on predictive models offers a transformative opportunity for institutions to support students in achieving their career aspirations while ensuring the continued excellence of their educational programs.

In addition, our research contributes significantly to the expanding domain of data mining applications within the field of education, with a particular focus on analyzing the performance of Electronics Engineering graduates in licensure examinations. It highlights the considerable potential of predictive models to reshape the educational landscape and underscores the pivotal role of data in nurturing academic accomplishments. Also, these insights offer invaluable direction for Higher Education Institutions (HEIs) and policymakers seeking to enhance graduates' achievements in licensure examinations, thus fostering a more promising future for both students and educational institutions.

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Ensemble-Based Prediction Model for Enhanced Electronics Engineering Licensure Examination Results Using Student Performance Analysis

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Abstract:
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I. Introduction

Higher education institutions (HEIs) play a critical role in equipping graduates with the necessary knowledge, skills, and experiences to succeed in today's fiercely competitive labor markets. To ensure the professional readiness of graduates, licensure examinations have become a prerequisite ... in many countries. The performance of HEI graduates in these examinations has emerged as ... lity, reflecting the effectiveness of instruction and curriculum design [1] [2]. In the Philippines, ... regulatory mechanisms for professional practice across different fields, and HEIs have increasingly focused on improving their graduates' performance in these examinations by

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> *** Comments: Comments to the authors

In this paper, the authors discuss the ensemble-based prediction model for enhanced electronics engineering license examination results using student performance analysis. The paper has been written in a good writing format and has an interesting discussion. However, there are several revision points to improve the quality of the paper.
1. In the related work section, authors need to discuss the differences between related research and this research. Showing the research gaps and advantages of this research proposal.
2. The research method needs to be clarified by adding a block diagram that describes the workflow of the system, then explaining it comprehensively.
3. The format for writing decimal values needs to be uniform, for example, it is only limited to two decimal places.

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> *** Quality: - Is the paper technically sound? How are its claims backed up?
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Good (3)

> *** Clarity: - Is the paper clearly written? Does it motivate the research? Does it describe clearly the methods employed (e.g., experimental procedures, algorithms, analytical tools), if any?
- Are the results, if any, described and evaluated thoroughly?
- Is the paper organized in a sensible and logical fashion?
Fair (2)

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- Does it involve or synthesize ideas, methods, approaches from multiple disciplines?
- Does it have interesting implications for multiple disciplines?*
Good (3)

> *** Comments: Comments to the authors

In the results and discussion of this research, it has not been well revealed that the illustration of the contribution to the application of data mining techniques in the educational environment, especially in analyzing th performance of the Electronic Engineering license exam. Add an explanation of implementation illustrations accompanied by relevant and new references within the last 5 years.

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Ensemble-Based Prediction Model for Enhanced Electronics Engineering Licensure Examination Results Using Student Performance Analysis

Mr. Pitz Gerald G. Lagrazon, Ms. Jennifer Edytha E Japor, Prof. Maria Rossana D. De Veluz, Prof. Loretta P. Arroyo, Dr. Frederick T. Villa and Dr. Maria Corazon B. Abejo

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