

Data-Driven Prediction and Recommendation of Elective Courses for Master's Students

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Abstract

This study presents a machine learning–based framework designed to predict students' academic performance in elective courses and the resulting impact on other core courses within the same semester. Using data collected from the Department of Geography and Environmental Science, Begum Rokeya University, Rangpur (BRUR), various models—including Logistic Regression, Decision Tree, Support Vector Classification, Naïve Bayes, and Random Forest Classification—were trained and evaluated. The dataset underwent preprocessing, encoding, and correlation analysis using Pearson, Spearman, and Kendall methods to identify inter-course relationships. Among all models, the Random Forest Classification algorithm achieved the highest performance with 78% accuracy, an R^2 score of 0.80, and a MAPE of 22%, effectively capturing nonlinear dependencies between core and elective results. The model successfully predicted both elective course performance and the influence of elective selection on other courses of the same semester. These findings demonstrate the potential of machine learning for data-driven academic advising, enabling universities to recommend electives that align with students' academic strengths. The framework lays the foundation for developing an automated elective course recommendation system to enhance student performance and decision-making in higher education.

Keywords

Elective Course Prediction, Elective Course Recommendation System, Correlation Among Courses, and Core Course Result Prediction.

1. Introduction

The selection of a course or subject can influence not only grades and results but also motivation, learning experience, and long-term academic success, so selecting the proper course or subject is one of the most important factors in education. Students' tendency in selecting courses is generally to achieve higher grades or satisfy external motivation (Gong et al., 2024). Students mostly try to avoid difficult courses unless it is necessary, but in the case of higher-achieving students, they are more likely to select challenging, high-value courses, which can further help in achieving their academic goal (Babad and Tayeb, 2003; Gong et al., 2024). Early advising for students through course performance evaluation can help students get better outcomes and adjust their course selection (Nachouki and Naaj, 2022). A system that can recommend courses based on the student's past performance can help boost CGPA (Oladipo et al., 2021). A data-driven decision-making process can outperform traditional approaches of selecting elective courses in studies (George and Lal, 2021). Selecting electives that align with a student's strengths and interests can lead to better grades and overall academic success. Students often choose electives based on perceived workload and grading criteria, aiming to maximize their GPA, sometimes at the expense of personal interest or challenge. However, making informed and strategic elective choices—potentially with the help of recommendation systems or academic advisors—can optimize both learning and performance outcomes (Srivastava et al., 2024). The autonomy to choose electives fosters intrinsic motivation, deeper engagement, and satisfaction with the learning process. When students

select courses that match their interests or career goals, they are more likely to be motivated, confident, and invested in their studies. Conversely, poor elective choices can lead to disengagement and missed opportunities for skill development (Cho et al., 2021). Elective courses offer students the chance to explore potential career paths, develop new skills, and broaden their academic horizons. Well-chosen electives can clarify career interests, enhance employability, and provide hands-on experience in specialized fields. Universities are encouraged to support students in making informed elective choices to better prepare them for future careers (Fan, 2023). Elective courses offer students the chance to explore potential career paths, develop new skills, and broaden their academic horizons. Well-chosen electives can clarify career interests, enhance employability, and provide hands-on experience in specialized fields. Universities are encouraged to support students in making informed elective choices to better prepare them for future careers (Devi et al., 2025). Poorly chosen electives may lead to disengagement, lower achievement, or missed opportunities to build relevant expertise. Electives tailored to a student's personality and aspirations can maximize both academic success and career planning, while misaligned choices can hinder skill acquisition and competitiveness in the job market (Naik et al., 2023). When students choose electives based on genuine interest or domain expertise, they are more likely to be motivated, engaged, and successful. Conversely, selecting electives due to peer influence, lack of information, or perceived ease can result in dissatisfaction, course withdrawal, or underperformance. Studies show that improper elective selection often leads to students dropping courses or failing to achieve desired outcomes, highlighting the need for informed and intentional choices (Altunbay, 2018). Electives offer a chance to broaden perspectives, develop interdisciplinary skills, and foster personal growth. They can deepen understanding, encourage intellectual curiosity, and support the development of critical thinking and adaptability—qualities valued in both academic and professional settings (Movchan and Zarishniak, 2017).

A few studies have been performed considering the elective course selection, its importance, factors influencing the selection of elective courses, and its impact on job, career, and also in skill development opportunities. But there's no research work that simultaneously predicts the grade of an elective course based on previous performances and also the other courses grade of the same semester. This study aims to use machine learning algorithms to predict the grade of elective courses based on previous performances, and also predicts the other courses' results due to the selection of different elective courses, and at the end suggests by elective course selection by optimizing overall CGPA.

1.1 Objectives

The objectives of this research revolve around:

- To successfully predict students' performance in elective courses using machine learning models based on their previous academic results,
- To analyze the relationships between core and elective courses through exploratory data analysis and correlation methods.
- To predict the impact of elective course selection on the performance of other core courses taken in the same semester.
- To propose a data-driven elective recommendation approach that helps students choose electives that maximize overall academic performance.

2. Literature Review

In this section, several research works have been organized based on prevalence, factors, and methodology used. There are significant numbers of studies that highlight the factors influencing the selection of elective courses for students. While a systematic literature suggests that academic data (university/college major, GPA, course grades, entrance score), demographic data (age, gender, ethnicity), student preferences, academic performance, career aspirations, and feedback from previous students highly influence in selection of courses (Kamal et al., 2024). Another literature review suggests that students' tastes and preferences, student–course interaction data, and course features influence the decision-making of elective course selection (Algarni and Sheldon, 2023). A paper suggests that learning style, user behavior, and user profiles, which may include contextual and demographic information, influence the selection of an elective course (Urdaneta-Ponte et al., 2021). The paper also suggests that job competencies can be used to recommend courses. A research paper summarized the use of recommender systems in education in the education domain (Rivera et al., 2018). Research was focused on different recommender system methodologies and the challenges they face (Lynn and Emanuel, 2021). While there is significant research on factors influencing the decision-making of elective courses, there is limited research on using data-driven decision-making for recommendations of elective courses. A research paper has reviewed various machine learning algorithms used to design course recommendation systems in higher education (Kalokhe and Kumbhar, 2024). This also suggests building a course

recommendation system that can help students select courses that align with their career paths and interests. A research used a predict-then-optimize framework to optimize preparatory leave days (Islam et al., 2024). While a study has developed a logistic regression model that predicts students’ outcome on elective courses based on previous course performance but does not consider the effect of elective courses on other courses of the semester (Oladipo et al., 2021). A study used K-Nearest Neighbor Algorithm-based recommendation to suggest elective course selection for undergraduate courses (Ogunde and Ajibade, 2019). Another study used a collaborative-based recommendation approach, specifically the Pearson Correlation Coefficient, to suggest courses by comparing similarities in students’ course templates (Bhumichitr et al., 2017). Research developed a new recommendation system that helps students select courses matching their interests and academic performance (Esteban et al., 2020). Currently there are no studies that predicts the performance on elective courses and effect on other courses as well by predicting academic grades and using an optimization algorithm to suggest an elective course to maximize academic performance for masters courses.

3. Methods

This study aims to predict Master’s students’ grades in elective courses using machine learning techniques and to recommend suitable electives based on predicted performance. The process involves four main stages: data collection and preprocessing, feature selection, model training and testing, and performance evaluation.

The following flow chart shows the overall methodology of this research (Figure 1):

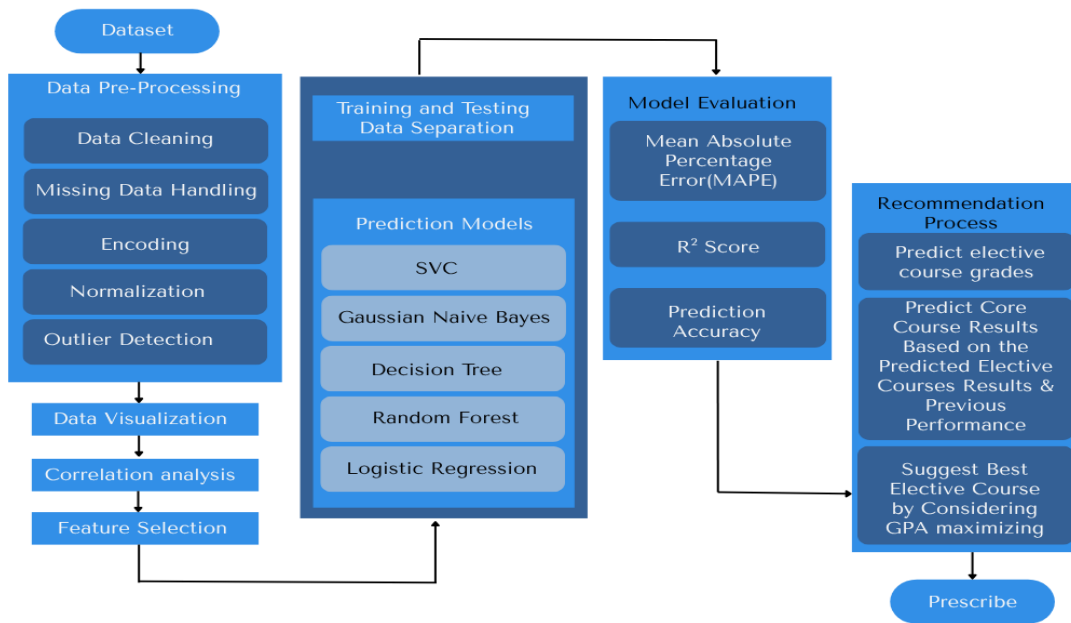


Figure 1. Methodology overview

3.1 Data Collection

The dataset for this research was collected from the Department of Geography and Environmental Science, Begum Rokeya University, Rangpur (BRUR). It includes the Master's program students' academic results, encompassing both core and elective courses across multiple academic sessions. The dataset captures course codes, grades, and cumulative GPAs for each student, enabling trend and performance analysis across subjects.

3.2 Data Preprocessing

The collected dataset required extensive preprocessing to ensure accuracy and consistency before applying machine learning techniques.

Key preprocessing steps included:

- **Data Cleaning:** Removal of duplicate records and correction of inconsistent grade formats.
- **Missing Data Handling:** Missing grades were imputed using statistical averages.
- **Encoding:** Grades and course identifiers were converted into numerical values through label encoding and one-hot encoding.
- **Normalization:** Data was normalized to ensure uniform scaling of attributes.
- **Outlier Detection:** Statistical analysis was used to identify and remove outliers that could distort model performance.

These steps ensured that the dataset was ready for both exploratory and predictive analysis.

3.3 Exploratory Data Analysis (EDA) and Correlation Analysis

Before model training, Exploratory Data Analysis (EDA) was conducted to understand the structure of the dataset, identify patterns in enrollment and performance, and detect anomalies. Enrollment distribution, grade frequencies, and performance variations across electives were analyzed.

To examine how performance in core courses relates to elective outcomes, correlation analyses were performed using Pearson, Spearman, and Kendall coefficients.

These methods provided insight into linear, rank-based, and ordinal associations between courses. The strongest correlations were later used as predictive features in the machine learning models.

3.4 Model Development

Five supervised machine learning algorithms were used to predict elective course grades:

- Support Vector Classifier (SVC)
- Gaussian Naive Bayes
- Decision Tree Classifier
- Random Forest Classifier
- Logistic Regression

Each model was trained using the prepared dataset and tested to evaluate its prediction performance. These models were chosen for their proven effectiveness in classification problems and their ability to handle both linear and non-linear relationships in data.

3.5 Model Evaluation

Model performance was assessed using three key metrics: Accuracy, R² Score, and Mean Absolute Percentage Error (MAPE). These metrics help evaluate both the correctness and consistency of the model predictions.

Accuracy

Accuracy measures the proportion of correctly predicted outcomes among all predictions.

$$\text{Accuracy} = (\text{TP} + \text{TN}) / (\text{TP} + \text{TN} + \text{FP} + \text{FN}) \quad (\text{Eq. 1})$$

where: TP = True Positives, TN = True Negatives, FP = False Positives, FN = False Negatives. A higher accuracy value indicates better model performance.

R² Score (Coefficient of Determination)

The R² score evaluates how well the predicted values fit the actual data.

$$R^2 = 1 - \frac{\sum (y_i - \hat{y}_i)^2}{\sum (y_i - \bar{y})^2} \quad (\text{Eq. 2})$$

where: y_i = actual values, \hat{y}_i = predicted values, \bar{y} = mean of the actual values. An R² value closer to 1 indicates a stronger correlation between predictions and actual outcomes.

Mean Absolute Percentage Error (MAPE)

MAPE measures the average percentage difference between the predicted and actual values.

$$\text{MAPE} = \frac{1}{n} \sum_{i=1}^n \left| \frac{y_i - \hat{y}_i}{y_i} \right| \times 100 \quad (\text{Eq. 3})$$

A lower MAPE value represents higher prediction accuracy.

3.6 Recommendation Process

Based on the model predictions, elective courses were recommended to students according to their expected grades. The system suggests courses where the predicted performance is higher, helping students make informed decisions that can improve their CGPA and overall academic success.

4. Data Analysis

4.1 Exploratory Data Analysis

Student Enrollment and Performance Trends

To understand student preferences and outcomes, enrollment statistics and academic performance across elective courses were analyzed.

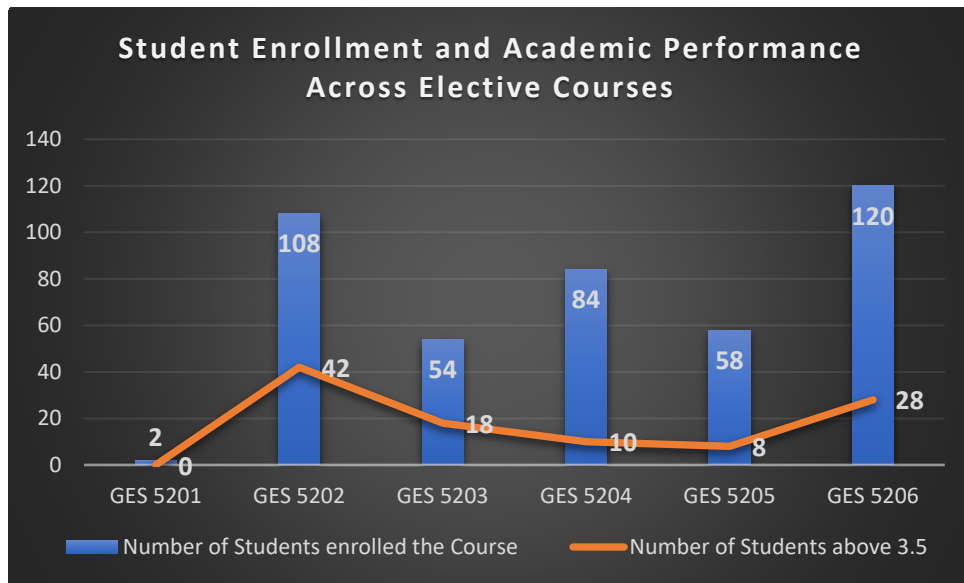


Figure 2. Student Enrollment and Academic Performance Across Elective Courses

From Figure 2, it can be said that enrollment and performance vary considerably across elective courses:

- GES 5206 attracted the highest number of students (120), with 28 students achieving a GPA above 3.5.

- GES 5202 also showed strong engagement (108 students) and the highest number of high achievers (42 students).
- Courses such as GES 5203, GES 5204, and GES 5205 exhibited moderate enrollment (ranging from 54–84 students) but relatively lower counts of high-performing students, indicating higher grading difficulty or greater course complexity.
- GES 5201 had minimal enrollment (2 students) with no high performers, suggesting low preference or course difficulty.

These findings suggest that elective selection among students is influenced by perceived ease, interest alignment, and potential for grade maximization.

4.2 Correlation Analysis

To explore the interrelationships between core and elective courses, multiple correlation analyses were conducted using Pearson, Spearman, and Kendall correlation coefficients.

Each method captures a different perspective on how the performance in core courses relates to performance in elective courses.

Pearson Correlation Analysis

The Pearson correlation coefficient measures the linear relationship between core and elective course results.

From the Pearson heatmaps, several strong positive correlations are observed, including (Figure 3 and Figure 4):

- GES 5103 & GES 5207 ($r = 0.88$)
- GES 5103 & GES 5209 ($r = 0.75$)
- GES 5104 & GES 5211 ($r \approx 0.98$)

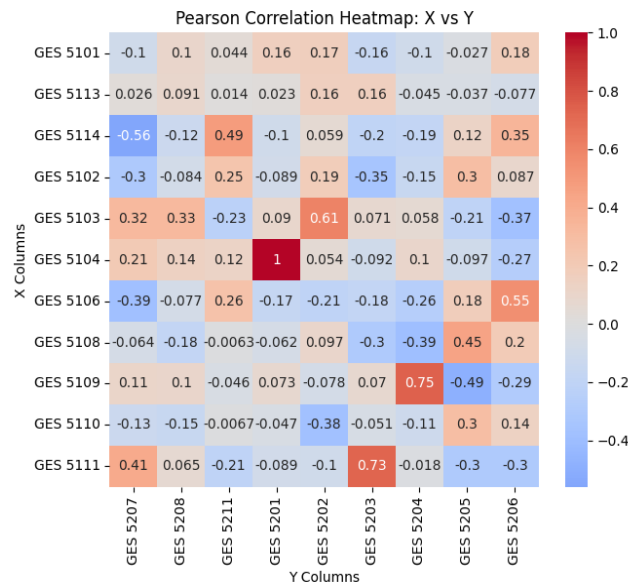


Figure 3. Pearson Correlation Analysis for Non-Thesis Students

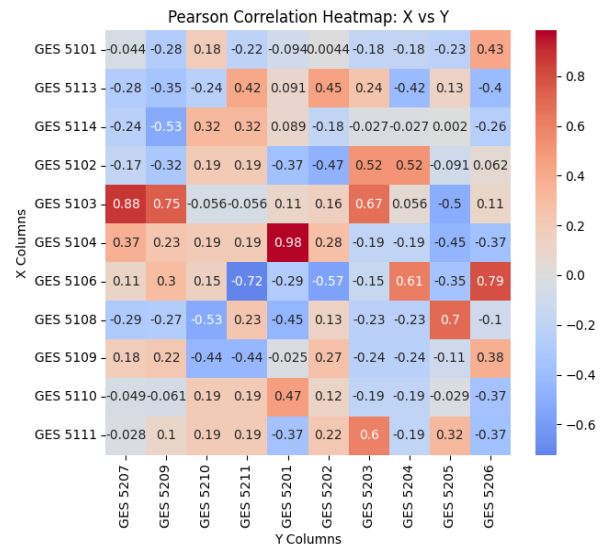


Figure 4. Pearson Correlation Analysis for Thesis Students

These indicate that students who perform well in these specific core subjects tend to perform equally well in their corresponding electives. Moderate correlations are found between GES 5106 & GES 5205 ($r = 0.61$) and GES 5106 & GES 5206 ($r = 0.79$), showing a partial overlap of skills and competencies. Negative correlations (e.g., between GES 5102 & GES 5203, GES 5104 & GES 5204) suggest weaker predictive relationships, implying that these electives assess different abilities (Figure 5 and Figure 6).

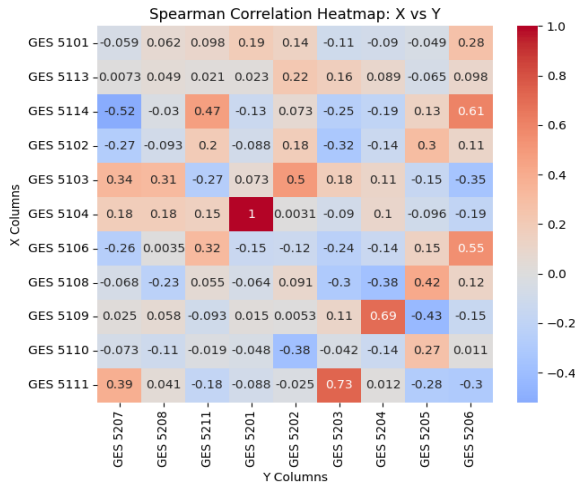


Figure 5. Spearman Correlation Analysis for Non-Thesis Students

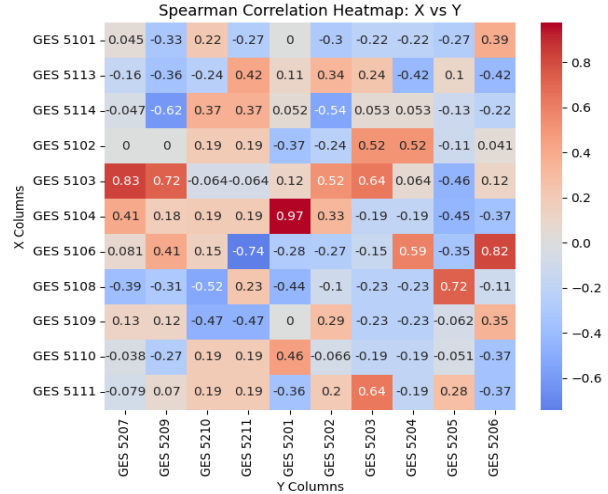


Figure 6. Spearman Correlation Analysis for Thesis Students

Spearman Correlation Analysis

The Spearman rank correlation measures monotonic (rank-based) relationships, capturing nonlinear trends that Pearson may miss.

The Spearman results reinforced the positive associations found in the Pearson analysis, though with slightly lower correlation strengths due to the ranking-based nature of the test.

The strongest Spearman correlations include:

- GES 5103 & GES 5207 ($\rho = 0.83$)
- GES 5103 & GES 5209 ($\rho = 0.72$)
- GES 5104 & GES 5211 ($\rho \approx 0.97$)

This indicates that improvements in core course rankings are consistently associated with improvements in corresponding elective rankings, confirming that academic success patterns are stable across related subjects (Figure 7 and Figure 8).

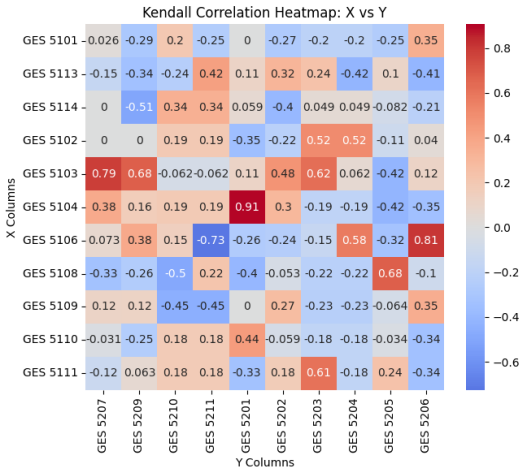


Figure 7. Kendall Correlation Analysis for Thesis Students

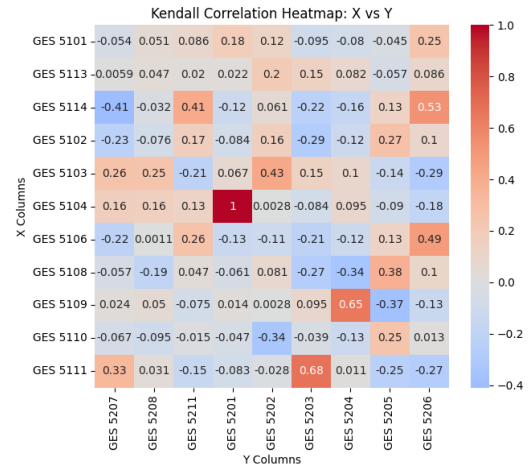


Figure 8. Kendall Correlation Analysis for Non-Thesis Students

Kendall Correlation Analysis

The Kendall Tau correlation measures the ordinal association between two variables, offering a more conservative but robust measure of dependency.

Kendall results exhibit patterns similar to Pearson and Spearman, with the highest correlations observed for:

- GES 5103 & GES 5207 ($\tau = 0.79$)
- GES 5104 & GES 5211 ($\tau \approx 0.91$)
- GES 5106 & GES 5205 ($\tau = 0.58$)

These consistent high correlations across all three methods validate the reliability of the observed relationships between core and elective courses. The concordance among Pearson, Spearman, and Kendall metrics suggests that the relationship between these course pairs is both linear and monotonic, highlighting strong conceptual and performance-based connections.

Overall, these analyses demonstrate that students’ performance in key core courses can reliably predict outcomes in related electives. The consistent results across Pearson, Spearman, and Kendall methods strengthen the validity of this conclusion and support the subsequent use of these correlations as input features in the machine learning prediction model.

5. Results and Discussion

5.1 Numerical Results

Five machine learning models—Logistic Regression, Decision Tree, Support Vector Classification (SVC), Naïve Bayes, and Random Forest—were trained and tested on the processed dataset.

Performance was evaluated using Accuracy, R² Score, and MAPE (Table 1).

Table 1. Comparison of Machine Learning Model Performance

Model	Accuracy (%)	R ² Score	MAPE (%)
Logistic Regression	66	0.65	34
Decision Tree Classification	72	0.74	28
Support Vector Classification (SVC)	75	0.77	25
Naïve Bayes Classification	71	0.69	30
Random Forest Classification	78	0.8	22

Among all the tested algorithms, the Random Forest Classification model achieved the highest performance, with:

- Accuracy: 78%
- R² Score: 0.80
- MAPE: 22%

This indicates that the Random Forest model can reliably predict approximately four out of five student outcomes, with an average error margin of only 22%.

The high R² value confirms that nearly 80% of the variation in elective course grades can be explained by the input variables — namely, students' performance in core and prior courses.

The Random Forest model's superior performance can be attributed to its ensemble learning mechanism, which combines multiple decision trees to capture both linear and nonlinear relationships within the data. Unlike single-tree models or linear regressors, it reduces overfitting and provides more stable and generalized predictions.

These findings are consistent with previous research (e.g., Nachouki & Naaj, 2022; Oladipo et al., 2021) that identified Random Forest as a highly effective algorithm for academic performance prediction due to its ability to handle mixed feature types and complex interdependencies.

The obtained results confirm that machine learning models can effectively predict students' academic performance in elective courses based on their previous grades. Among the models, Random Forest Classification offers the best trade-off between accuracy, interpretability, and computational efficiency. The system can predict likely performance outcomes for each elective course before enrollment, helping students make informed choices aligned with their strengths and academic goals.

For example, if a student performs strongly in courses like GES 5103 and GES 5104, which show high correlation with GES 5207 and GES 5211 respectively, the model can recommend those electives as optimal options to maximize CGPA.

5.2 Implications for Academic Decision-Making

The implementation of this ML-based framework can have several practical implications:

- **Predictive Academic Advising:**
Advisors can use the model to forecast a student's likely performance in different electives and guide them toward the most suitable options.
- **Course Recommendation System:**
The trained Random Forest model can be integrated into an automated recommendation tool, where students input their previous results to receive tailored elective suggestions.
- **Performance Optimization:**
Students can strategically choose electives aligned with their academic strengths, thereby improving their overall CGPA and confidence.

6. Conclusion

This study successfully achieved its objectives by developing a machine learning-based framework that not only predicted students' performance in elective courses but also predicted the performance of other core courses in the same semester based on the chosen elective.

Among the applied models, the Random Forest Classification algorithm demonstrated the best performance, achieving 78% accuracy, an R² score of 0.80, and a MAPE of 22%, confirming the model's reliability and predictive strength. The findings imply that machine learning can effectively support data-driven academic advising, helping students make informed decisions about elective course selection by not only predicting the elective courses' results but also their effect on other core courses in that semester.

Such predictive insights can improve curriculum design, enhance student performance, and contribute to evidence-based academic planning.

For future work, this framework can be extended into a fully automated elective course recommendation system, incorporating factors such as student interests, learning styles, and career aspirations. Expanding the dataset across departments and universities will further strengthen model generalization and improve recommendation accuracy.

In summary, this research demonstrates that machine learning can accurately predict elective and core course performance simultaneously, establishing a strong foundation for data-driven elective course recommendation systems in higher education.

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Biographies

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Kamrul Hasan received his B.Sc. in Industrial and Production Engineering from Shahjalal University of Science and Technology (SUST), Bangladesh. His research interests include sustainable product design, environmentally conscious engineering, material efficiency, and simulation-based analysis. He has completed academic and project work spanning supply chain management, manufacturing systems, and human factors. Kamrul's recent thesis focused on enhancing material salvage and efficiency through environmentally conscious design and simulation methods. He is currently preparing for advanced studies abroad and aims to contribute to research in sustainable engineering and digital manufacturing.