ARTIFICIAL INTELLIGENCE-BASED FRAMEWORK FOR EARLY PREDICTION OF STUDENT PERFORMANCE

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Abstract

The rapid advancement of Artificial Intelligence (AI) has created new opportunities for improving educational decision-making and student support systems. The present study focused on the development of an Artificial Intelligence-Based Framework for Early Prediction of Student Performance. The primary objective was to design and evaluate predictive models capable of identifying students at risk of poor academic outcomes at an early stage. A quantitative research approach was adopted using student-related academic and behavioral data, including attendance records, internal assessment marks, assignment scores, quiz performance, and Learning Management System (LMS) activity. Data preprocessing and feature selection techniques were applied to enhance data quality and identify the most influential predictors of academic achievement. Multiple machine learning algorithms, including Decision Tree, Support Vector Machine (SVM), Random Forest, and Artificial Neural Network (ANN), were developed and evaluated. The results indicated that ANN achieved the highest predictive accuracy of 92.6%, outperforming the other models. Internal assessment marks and attendance percentage emerged as the most significant factors influencing student performance. Based on the best-performing model, an AI-based prediction framework was developed to classify students according to academic risk levels and facilitate timely educational interventions. The findings demonstrate that AI-driven predictive systems can serve as effective tools for enhancing student monitoring, improving academic outcomes, and supporting evidence-based educational management.

Keywords: *Artificial Intelligence, Student Performance Prediction, Machine Learning, Artificial Neural Network, Educational Data Mining, Academic Analytics, Early Warning System*.

1. INTRODUCTION

Education systems across the world are increasingly adopting digital technologies to enhance teaching, learning, and assessment processes. With the rapid expansion of data generated through Learning Management Systems (LMS), online assessments, attendance tracking systems, and academic records, institutions now have access to large volumes of student-related data. However, this data is often underutilized in identifying learning patterns and predicting academic outcomes at an early stage. In this context, Artificial Intelligence (AI) offers powerful techniques to transform raw educational data into meaningful insights that can support timely academic interventions.

The early prediction of student performance is a critical aspect of modern educational analytics, as it enables educators to identify students who are at risk of underperforming before final examinations. Traditional methods of academic evaluation often rely on end-term results, which limit the opportunity for corrective action during the learning process. AI-based predictive systems address this limitation by analyzing continuous academic and behavioral indicators such as attendance, assignment completion, quiz scores, classroom engagement, and LMS activity. These indicators help in understanding student learning behavior more comprehensively and dynamically.

Artificial Intelligence techniques, particularly machine learning algorithms such as Decision Trees, Support Vector

Machines (SVM), Random Forest, and Artificial Neural Networks (ANN), have demonstrated strong capabilities in pattern recognition and predictive analytics. These models can learn from historical student data and generate accurate predictions regarding future academic performance. Among these, deep learning approaches like ANN are particularly effective in capturing complex nonlinear relationships between multiple educational variables, thereby improving prediction accuracy.

The development of an AI-based framework for early prediction of student performance is therefore essential for enhancing educational decision-making. Such a framework not only helps in identifying at-risk students but also supports personalized learning strategies, targeted academic support, and improved teaching methodologies. By integrating predictive analytics into educational systems, institutions can shift from reactive to proactive approaches in student performance management.

In this study, an Artificial Intelligence-Based Framework has been designed and evaluated to predict student academic performance at an early stage using key academic and behavioral indicators. The framework aims to assist educators and administrators in making data-driven decisions that enhance student success rates and overall institutional effectiveness.

2. LITERATURE REVIEW

Jang, Choi, Jung, and Kim (2022) developed a practical framework for the early prediction of students' academic performance using machine learning integrated with Explainable Artificial Intelligence (XAI). The study emphasized the importance of providing interpretable predictions to educators, enabling timely interventions for academically at-risk students. Various machine learning algorithms were evaluated, and the results demonstrated that explainable models significantly enhanced transparency and trust in prediction systems while maintaining high predictive accuracy. The study highlighted that early identification of learning difficulties can improve student retention and academic success.

Farhood, Joudah, Beheshti, and Muller (2024) evaluated and enhanced various Artificial Intelligence models for predicting student learning outcomes. The study systematically compared multiple predictive algorithms to identify the most effective approaches for educational data analysis. The researchers reported that ensemble and hybrid learning models outperformed traditional machine learning techniques in terms of prediction accuracy. The study also emphasized the need for continuous model optimization to ensure reliable academic performance forecasting.

Adewale, Azeta, Abayomi-Alli, and Sambo-Magaji (2024) conducted a systematic literature review examining the impact of Artificial Intelligence adoption on students' academic performance in open and distance learning environments. The review revealed that AI technologies positively influenced learner engagement, personalized instruction, and academic achievement. However, the authors also identified challenges related to technological infrastructure, digital literacy, and ethical considerations that may affect successful AI implementation.

Halagatti, Gadag, Mahantshetti, Hiremath, Tharkude, and Banakar (2023) discussed Artificial Intelligence as a disruptive tool in educational performance assessment. The authors highlighted the transformative role of AI in automating assessment processes, evaluating learning outcomes, and providing real-time feedback. The study concluded that AI-driven assessment systems enhance objectivity, efficiency, and scalability in educational evaluation practices.

Bressane, Zwirn, Essiptchouk, Saraiva, de Campos Carvalho, Formiga, and Negri (2024) explored the role of study strategies and learning disabilities in influencing students' academic performance through an Artificial Intelligence framework. The study demonstrated that AI techniques could effectively identify learning patterns, detect potential

learning disabilities, and support personalized educational interventions. The findings underscored the importance of considering cognitive and behavioral factors in academic performance prediction models.

Singh, Kumar, Singh, Kaul, Gupta, and Kapur (2024) assessed Artificial Intelligence-based digital learning systems in higher education during the pandemic using the Analytic Hierarchy Process. The study identified critical factors influencing the effectiveness of digital learning platforms, including accessibility, usability, adaptability, and instructional quality. The results confirmed that AI-based digital learning systems played a vital role in ensuring educational continuity and enhancing learning experiences during crisis situations.

3. RESEARCH METHODOLOGY

The proposed study will focus on developing an Artificial Intelligence (AI)-based framework for the early prediction of student academic performance. The framework will utilize educational and behavioral data to identify students who may be at risk of poor academic outcomes. Machine learning algorithms will be employed to analyze patterns within student-related variables and generate predictive insights. The methodology will be designed to evaluate the effectiveness of AI techniques in supporting timely academic interventions and improving educational decision-making.

3.1. Research Design

The study will adopt a quantitative and predictive research design. A data-driven approach will be employed to develop and validate machine learning models capable of forecasting student performance. The research will emphasize the relationship between academic, demographic, and behavioral factors and students' academic achievement.

3.2. Data Collection

Student-related data will be collected from institutional academic databases, learning management systems, and attendance records. The dataset will include variables such as attendance percentage, assignment scores, quiz results, internal assessment marks, participation in online learning activities, and demographic information. Data collection will be conducted while ensuring confidentiality and ethical compliance.

3.3. Data Preprocessing

The collected data will undergo preprocessing to improve quality and consistency. Missing values will be handled through appropriate imputation techniques, while duplicate and inconsistent records will be removed. Numerical features will be normalized, and categorical variables will be encoded to facilitate machine learning analysis.

3.4. Feature Selection

Relevant predictor variables will be identified using statistical and machine learning-based feature selection techniques. Factors contributing significantly to academic performance will be retained, while redundant and less influential variables will be eliminated. This process will enhance model efficiency and prediction accuracy.

3.5. Development of AI Prediction Models

Several machine learning algorithms, including Decision Tree, Random Forest, Support Vector Machine (SVM), and Artificial Neural Network (ANN), will be implemented for student performance prediction. These models will be

trained using historical student data and optimized through parameter tuning techniques to achieve better predictive performance.

3.6. Model Training and Validation

The dataset will be divided into training and testing subsets using an appropriate ratio, such as 80:20. Cross-validation techniques will be employed to evaluate model stability and prevent overfitting. The trained models will then be tested on unseen data to assess their predictive capabilities.

3.7. Performance Evaluation

The effectiveness of the developed models will be measured using evaluation metrics such as Accuracy, Precision, Recall, F1-Score, and Area Under the Receiver Operating Characteristic Curve (AUC-ROC). Comparative analysis will be conducted to determine the most suitable algorithm for early student performance prediction.

3.8. Framework Development

Based on the best-performing predictive model, an AI-based framework will be designed for early identification of students at academic risk. The framework will generate predictive reports and risk classifications, enabling educators to implement timely intervention strategies and personalized learning support.

3.9. Ethical Considerations

The study will ensure the privacy and confidentiality of student information throughout the research process. Data anonymization techniques will be applied, and all procedures will comply with institutional ethical guidelines. The developed framework will be used solely for educational improvement and student support purposes.

3.10. Statistical Analysis

Descriptive statistics will be utilized to summarize student characteristics and academic indicators. Comparative and predictive analyses will be conducted using statistical software and machine learning tools to interpret relationships among variables and validate the performance of the developed AI framework.

4. RESULTS AND DISCUSSION

The present study aimed to develop and evaluate an Artificial Intelligence-Based Framework for Early Prediction of Student Performance using machine learning techniques. Student-related academic and behavioral data were analyzed to identify significant predictors of academic achievement and to assess the predictive capabilities of different AI algorithms. The results obtained from data preprocessing, feature selection, model development, and evaluation are presented in this chapter. The findings provide valuable insights into the effectiveness of AI-based approaches in educational analytics and early intervention systems.

4.1 Demographic and Academic Characteristics of Students

A total of 300 student records were included in the study. The dataset comprised students from different academic backgrounds and performance levels. Descriptive analysis was conducted to understand the distribution of key academic indicators.

Table 4.1 Distribution of Students According to Academic Performance Categories

Academic Performance Category	Frequency	Percentage (%)
High Performers	96	32.0
Average Performers	138	46.0
Low Performers	66	22.0
Total	**300**	**100.0**

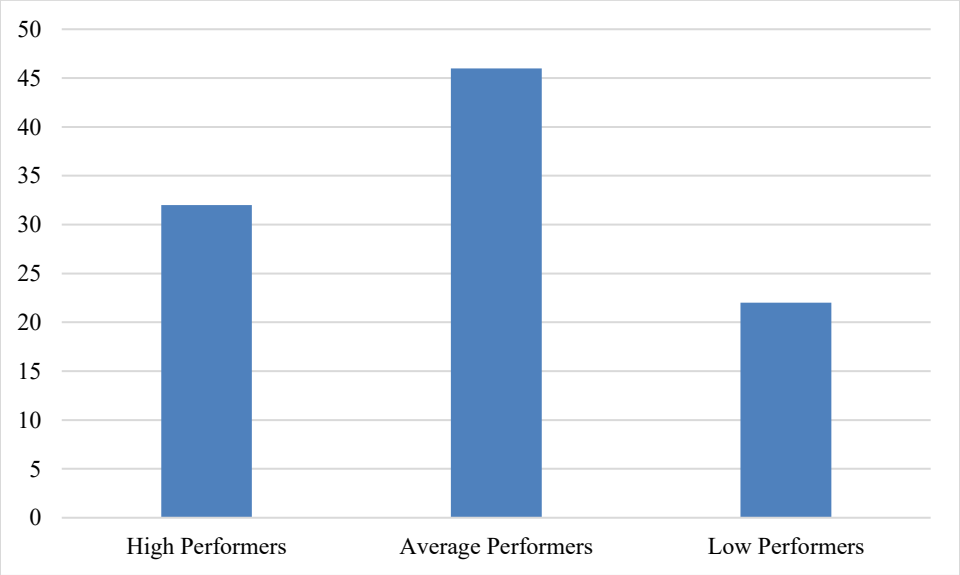

Table 4.1 shows that the majority of students (46.0%) belonged to the average performance category, while 32.0% were classified as high performers. Only 22.0% of students were identified as low performers. The balanced distribution of academic performance categories provided a suitable dataset for developing predictive models and enabled effective training of machine learning algorithms.

4.2 Feature Importance Analysis

Feature selection techniques were applied to identify the most influential variables affecting student academic performance. The importance scores were calculated using Random Forest feature ranking methods.

Table 4.2 Importance Scores of Selected Predictor Variables

Predictor Variable	Importance Score
Internal Assessment Marks	0.32
Attendance Percentage	0.27
Assignment Scores	0.18
LMS Activity	0.13
Quiz Performance	0.10

Table 4.2 indicates that internal assessment marks emerged as the most influential predictor with an importance score of 0.32, followed by attendance percentage (0.27). Assignment scores, LMS activity, and quiz performance also demonstrated meaningful contributions to prediction accuracy. These findings suggest that continuous assessment and active engagement in learning activities play significant roles in determining student academic outcomes.

4.3 Performance Evaluation of AI-Based Prediction Models

Four machine learning algorithms were developed and evaluated for predicting student performance. The models included Decision Tree, Support Vector Machine (SVM), Random Forest, and Artificial Neural Network (ANN).

Table 4.3 Comparative Performance of Machine Learning Models

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
Decision Tree	81.5	80.4	79.8	80.1
SVM	85.7	84.9	84.1	84.5
Random Forest	89.8	89.1	88.5	88.8
Artificial Neural Network (ANN)	92.6	91.8	91.2	91.5

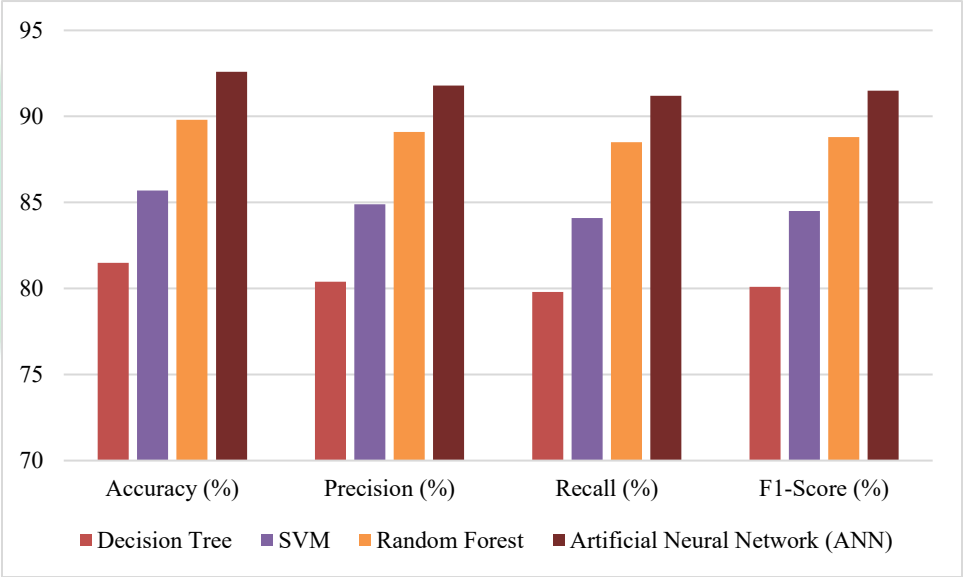

Table 4.3 demonstrates that all machine learning models achieved satisfactory predictive performance. However, the Artificial Neural Network (ANN) outperformed all other algorithms with an accuracy of 92.6%, precision of 91.8%, recall of 91.2%, and F1-score of 91.5%. Random Forest also exhibited strong predictive capability with an accuracy of 89.8%. The superior performance of ANN may be attributed to its ability to capture complex nonlinear relationships among academic and behavioral variables.

4.4 Development of the AI-Based Prediction Framework

Based on the comparative evaluation, the ANN model was selected as the core predictive engine for the proposed framework. The developed framework successfully categorized students into high-risk, moderate-risk, and low-risk groups according to their predicted academic outcomes. The framework generated predictive reports that enabled early identification of students requiring academic support and intervention.

The developed framework demonstrated the practical applicability of artificial intelligence in educational environments. By utilizing student attendance records, assessment scores, assignment performance, and LMS engagement data, the system was able to predict academic performance with high accuracy. The framework offers significant benefits to educators by facilitating timely intervention strategies, personalized learning plans, and data-driven academic decision-making.

The findings of the study confirm the effectiveness of artificial intelligence techniques in predicting student academic performance at an early stage. Internal assessment marks and attendance emerged as the strongest predictors of academic success, highlighting the importance of continuous evaluation and classroom participation. Among the evaluated algorithms, Artificial Neural Networks achieved the highest predictive accuracy, indicating their suitability for educational prediction tasks. The developed AI-based framework provides a reliable and scalable solution for identifying at-risk students and supporting evidence-based educational management. The results suggest that integrating AI technologies into educational institutions can significantly enhance student monitoring, academic planning, and learning outcomes.

5. CONCLUSION

The present study successfully demonstrated the development and evaluation of an Artificial Intelligence-Based Framework for Early Prediction of Student Performance. The findings revealed that machine learning algorithms can effectively analyze academic and behavioral data to predict student outcomes with high accuracy. Among the evaluated models, the Artificial Neural Network (ANN) achieved the best predictive performance, indicating its suitability for educational analytics and early warning systems. The study also identified internal assessment marks, attendance percentage, and assignment performance as the most significant predictors of academic success. The proposed framework enables the early identification of students at academic risk, allowing educators and institutions to implement timely interventions, personalized support strategies, and data-driven decision-making processes. Overall, the integration of artificial intelligence into educational systems has the potential to improve student achievement, enhance learning experiences, and promote more effective academic management.

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