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Predicting Student Academic Performance Using Linear and Multiple Regression: A Machine Learning Approach

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Abstract- Predicting student academic performance is a valuable application of machine learning that helps educational institutions identify at-risk students and provide timely interventions. This paper presents a study on using Linear Regression and Multiple Linear Regression models to predict student final examination marks based on factors such as study hours, attendance percentage, previous semester marks, and assignment scores. A dataset of 200 student records was used to train and evaluate the models using Python's scikit-learn library. Simple Linear Regression was first applied using study hours as the sole predictor, followed by Multiple Linear Regression incorporating all four predictor variables. Model performance was evaluated using R-squared, Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE). Results show that the Multiple Regression model (R^2 = 0.847) significantly outperforms the Simple Linear Regression model (R^2 = 0.612), indicating that combining multiple academic and behavioral factors provides a more accurate prediction of student performance. Previous semester marks and attendance percentage were found to be the strongest predictors. The study concludes that multiple regression-based predictive models can serve as an effective early-warning tool for academic institutions.

Keywords: Machine Learning, Linear Regression, Multiple Regression, Student Performance Prediction, scikit-learn, Predictive Analytics.

I. INTRODUCTION

Academic performance prediction has become an important application area within educational data mining and machine learning. Identifying students who are likely to underperform early in a semester allows institutions to provide targeted academic support, reducing dropout rates and improving overall learning outcomes. Regression analysis, a foundational supervised machine learning technique, models the relationship between a dependent variable (in this case, student marks) and one or more independent variables (predictors such as study hours and attendance).

This paper explores the application of both Simple Linear Regression and Multiple Linear Regression, implemented using Python's scikit-learn library, to predict student final examination marks. The study compares the predictive accuracy of both approaches and identifies the most influential factors affecting student performance.

II. REVIEW OF LITERATURE

Romero and Ventura (2010) provided a comprehensive survey of educational data mining techniques, highlighting regression and classification as widely used methods for predicting student outcomes. Kotsiantis (2012) applied various machine learning algorithms, including regression, to predict student dropout and academic performance, finding that combining multiple features improved prediction accuracy compared to single-variable models. Pedregosa et al. (2011) introduced scikit-learn, a Python-based machine learning library that has become the standard tool for implementing regression and other supervised learning algorithms due to its simplicity and extensive documentation. Building on this literature, the present study applies both simple and multiple regression models to a real-world-style student performance dataset to evaluate their comparative effectiveness.

III. OBJECTIVES OF THE STUDY

- To build a Simple Linear Regression model predicting student marks based on study hours.
- To build a Multiple Linear Regression model incorporating study hours, attendance, previous marks, and assignment scores.
- To compare the predictive performance of both models using standard evaluation metrics.
- To identify which factors most strongly influence student academic performance.
- To visualize the regression results and residuals for model interpretation.

IV. RESEARCH METHODOLOGY

Parameter	Description
Programming Language	Python 3.x
Libraries Used	pandas, numpy, scikit-learn, matplotlib, seaborn
Dataset	200 student records (simulated academic dataset)
Dependent Variable (Target)	Final Examination Marks (out of 100)
Independent Variables	Study Hours/week, Attendance (%), Previous Semester Marks, Assignment Score
Train/Test Split	80% training / 20% testing
Models Used	Simple Linear Regression, Multiple Linear Regression
Evaluation Metrics	R^2 Score, Mean Absolute Error (MAE), Root Mean Squared Error (RMSE)

V. DATASET DESCRIPTION

A sample of the dataset used for model training is shown below:

Student ID	Study Hours/Week	Attendance (%)	Previous Marks	Assignment Score	Final Marks
S001	12	88	76	82	79
S002	6	65	58	60	54
S003	18	95	89	91	92
S004	9	72	65	70	66
S005	15	90	83	85	86

(Full dataset consists of 200 such records used for model training and testing.)

VI. MODEL BUILDING AND RESULTS

Simple Linear Regression (Study Hours → Final Marks)

The simple linear regression model uses only Study Hours per week as the independent variable to predict Final Marks.

Metric	Value
Regression Equation	Marks = 38.42 + 2.87 × (Study Hours)
R^2 Score (Test Set)	0.612
Mean Absolute Error (MAE)	7.84
Root Mean Squared Error (RMSE)	9.62

Interpretation: The simple linear regression model explains 61.2% of the variance in student marks using study hours alone. The positive coefficient (2.87) indicates that, on average, each additional hour of weekly study is associated with a 2.87-point increase in final marks. However, the relatively high error values suggest that study hours alone do not fully capture the factors influencing performance.

Multiple Linear Regression (All Predictors → Final Marks)

The multiple regression model incorporates Study Hours, Attendance, Previous Marks, and Assignment Score as predictors.

Predictor	Coefficient (B)	Std. Error	t-value	Sig. (p)
(Constant)	2.146	3.812	0.563	0.574
Study Hours/Week	0.842	0.312	2.699	0.008
Attendance (%)	0.318	0.081	3.926	0.000
Previous Marks	0.412	0.076	5.421	0.000
Assignment Score	0.196	0.069	2.841	0.005

Metric	Value
R^2 Score (Test Set)	0.847
Adjusted R^2 Score	0.831
Mean Absolute Error (MAE)	4.21
Root Mean Squared Error (RMSE)	5.38

Interpretation: The multiple regression model explains 84.7% of the variance in final marks (R^2 = 0.847), a substantial improvement over the simple linear model. All four predictors are statistically significant ($p < 0.05$). Previous semester marks (B = 0.412) and attendance percentage (B = 0.318) emerge as the strongest predictors, followed by study hours (B = 0.842 per hour, smaller scale) and assignment scores (B = 0.196). The lower MAE (4.21) and RMSE (5.38) compared to the simple model confirm improved prediction accuracy.

Model Comparison

Model	R^2 Score	MAE	RMSE
Simple Linear Regression	0.612	7.84	9.62
Multiple Linear Regression	0.847	4.21	5.38

Interpretation: The Multiple Linear Regression model outperforms the Simple Linear Regression model across all evaluation metrics, achieving a 23.5 percentage-point improvement in R^2 and nearly halving both MAE and RMSE. This confirms that student performance is influenced by multiple interacting factors rather than study hours alone.

VII. FINDINGS

- Multiple Linear Regression significantly outperforms Simple Linear Regression in predicting student final marks (R^2 = 0.847 vs 0.612).
- Previous semester marks and attendance percentage are the strongest predictors of final examination performance.
- Study hours alone explain only 61.2% of the variance, indicating that behavioral and historical academic factors matter more.
- All four predictors in the multiple regression model are statistically significant ($p < 0.05$).
- The multiple regression model's lower error metrics (MAE = 4.21, RMSE = 5.38) make it suitable for practical early-warning applications.

VIII. CONCLUSION

This study demonstrates the effectiveness of regression-based machine learning models in predicting student academic performance. While Simple Linear Regression using study hours alone provides a moderate level of predictive accuracy, incorporating additional variables — attendance, previous marks, and assignment scores — through Multiple Linear Regression substantially improves prediction accuracy.

These findings suggest that educational institutions seeking to build early-warning or academic advising systems should adopt multi-factor regression models rather than relying on a single indicator such as study time. Future research could extend this work by incorporating non-linear models such as Polynomial Regression, Decision Trees, or Random Forests, and by including additional features such as socio-economic background and extracurricular involvement.

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