



Master Thesis Proposal

*A Predictive Model for Student Academic Performance in
Higher Education Using Advanced Machine Learning
Techniques*

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Chapter 1: Introduction and Overview

1.1 Overview

The landscape of higher education is undergoing a significant transformation driven by the rapid integration of artificial intelligence (AI) and machine learning (ML) technologies. Educational institutions are increasingly recognizing the value of data-driven decision-making to enhance teaching methodologies, optimize resource allocation, and ultimately improve student outcomes. Academic performance is a critical indicator of both student success and institutional quality. However, predicting this performance is a complex challenge, as it is influenced by a multitude of factors, including academic history, socio-demographic background, and behavioral patterns. Traditional methods of evaluating student progress often rely on retrospective analysis, which may be insufficient for timely interventions. In contrast, predictive analytics powered by machine learning offers a proactive approach, enabling educators to identify at-risk students early and provide targeted support. This research focuses on developing a robust predictive model for student academic performance using advanced machine learning techniques, aiming to bridge the gap between theoretical data science and practical educational applications.

1.2 Problem Definition

Despite the availability of vast amounts of educational data, many higher education institutions struggle to utilize this information effectively to prevent student failure and dropout. The core

problem lies in the inability to accurately and early predict which students are at risk of underperforming. Existing evaluation systems are predominantly reactive, assessing performance only after examinations or at the end of a semester, at which point interventions are often too late to be effective. Furthermore, student performance is not solely dependent on cognitive abilities but is a complex interplay of various features, including attendance, engagement, socio-economic status, and study habits. Therefore, there is a pressing need for an intelligent, automated system capable of analyzing these multidimensional datasets to forecast academic outcomes accurately. The challenge is to select and optimize the most appropriate machine learning algorithms that can handle the complexity of educational data and provide reliable predictions that educators can trust and act upon.

1.3 Thesis Objectives

The primary objective of this thesis is to design, implement, and evaluate a predictive model for student academic performance using machine learning algorithms. To achieve this overarching goal, the following specific objectives are defined:

1. To identify and analyze the key factors (academic, demographic, and behavioral) that significantly influence student academic performance.
2. To preprocess and explore a comprehensive educational dataset (e.g., the Student Performance Dataset from UCI Machine Learning Repository) to ensure data quality and suitability for modeling.
3. To develop and train multiple machine learning models, including but not limited to Random

Forest, Support Vector Machines (SVM), and Gradient Boosting algorithms, for predicting student success or failure.

4. To evaluate and compare the performance of the developed models using standard metrics such as Accuracy, Precision, Recall, and F1-Score.

5. To propose the most effective and interpretable machine learning framework that can be integrated into higher education systems for early warning and intervention.

1.4 Thesis Contribution

This research contributes to the field of Educational Data Mining (EDM) and Learning Analytics by providing a comprehensive empirical study on the application of advanced machine learning techniques for predicting student performance. The key contributions include:

1. A robust predictive framework: The study develops a highly accurate model capable of identifying at-risk students early in their academic journey, facilitating timely pedagogical interventions.

2. Feature importance analysis: By identifying the most critical variables affecting student outcomes, this research provides actionable insights for educators and policymakers to focus their resources effectively.

3. Comparative evaluation: The thesis offers a rigorous comparison of various machine learning algorithms on a standardized dataset, highlighting the strengths and limitations of each approach in an educational context.

4. Practical applicability: The proposed model is designed with practical implementation in mind, aiming to serve as a foundational tool for developing intelligent early warning systems in universities, particularly in distance learning environments like Midocean University.

1.5 Thesis Organization

The remainder of this thesis is organized as follows:

- * Chapter 2: Background and Related Work: This chapter reviews the fundamental concepts of machine learning and educational data mining, followed by a comprehensive survey of recent literature and related studies in the domain of student performance prediction.
- * Chapter 3: Proposed Approach (Methodology): This chapter details the research methodology, including data collection, preprocessing steps, feature selection, and the theoretical background of the chosen machine learning algorithms.
- * Chapter 4: Experimental Results and Discussion: This chapter presents the experimental setup, the results obtained from training and testing the models, and a detailed discussion comparing the performance of the different algorithms.
- * Chapter 5: Conclusion and Future Work: The final chapter summarizes the key findings of the research, highlights its limitations, and suggests potential directions for future studies in this field.

Chapter 2: Background and Related Work

2.1 Introduction to Educational Data Mining and Machine Learning

Educational Data Mining (EDM) is an emerging interdisciplinary research area that applies data mining techniques to educational data to address educational research problems [1]. It involves developing methods to explore the unique types of data that come from educational settings and using those methods to better understand students and the settings in which they learn [2]. Machine Learning (ML), a subfield of artificial intelligence, provides the computational tools necessary for EDM, enabling systems to learn from data without being explicitly programmed. In the context of student performance prediction, ML algorithms can identify complex patterns and relationships within large datasets, offering insights that traditional statistical methods might miss [3].

2.2 Related Work on Student Performance Prediction

Predicting student academic performance has been a significant area of research, with numerous studies employing various machine learning techniques to identify at-risk students

and improve educational outcomes. Recent literature highlights a growing trend towards more sophisticated models and comprehensive analyses.

One notable study by Al-Shami et al. (2025) [4] emphasized the effectiveness of ensemble learning techniques in predicting student academic performance. They employed ten regression models, including K-Nearest Neighbors Regressor, Linear Regression, CatBoost, XGBoost, and AdaBoost, along with an ensemble voting regression (VR) algorithm. Their VR model achieved an RMSE of 0.1050, MAE of 0.0837, and R^2 of 0.9890 on one dataset, and an R^2 of 0.7716 on a more complex dataset, demonstrating its robustness and adaptability. The study also utilized LIME and SHAP for model interpretability, providing actionable insights for educators.

Xu and Kim (2024) [5] proposed a combination prediction method for students' performance based on an ant colony algorithm, further showcasing the diversity of ML approaches in this field. Similarly, Haron et al. (2025) [6] introduced a hybrid methodology integrating quantitative and qualitative components to identify students at risk of unsatisfactory academic results. While effective, their study suggested that predictive capacity could be enhanced with more robust ML techniques.

Vimarsha et al. (2024) [7] explored a co-evolutionary hybrid intelligence model for student performance prediction. Their work compared ML models for classifying teachers and

employed reinforcement learning (RL) for a multiclass student performance prediction model. Despite demonstrating RL's potential, the authors noted limitations in scalability and generalizability across diverse datasets.

Ahmed (2024) [8] utilized a clustering-based approach with K-means and Davies-Bouldin metrics to analyze critical features influencing student performance. The study found that the Support Vector Machine (SVM) algorithm achieved the highest prediction accuracy but did not explore alternative ML models for comparison. This highlights a common challenge in the field: the need for comprehensive comparisons across a wider range of algorithms.

Chen et al. (2023) [9] presented a bipartite network methodology combined with Louvain clustering for student performance prediction, focusing on educational data mining. Their approach demonstrated the utility of network analysis in understanding student interactions and their impact on academic outcomes.

Further research by Rizwan et al. (2025) [10] conducted a systematic literature review on identifying factors affecting student academic performance and engagement prediction in MOOCs using deep learning. They identified research findings and gaps, proposing a conceptual framework for developing future personalized and adaptive e-learning systems. Karim-Abdallah et al. (2025) [11] also performed a systematic review on the application of

machine learning algorithms in predicting academic performance in higher education institutes, emphasizing the monitoring capabilities of such models.

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