SMART INSTRUCTION: LEVERAGING MACHINE LEARNING TO PERSONALIZE ENGINEERING EDUCATION THROUGH DATA ON LEARNING BEHAVIORS

ABSTRACT

The integration of Artificial Intelligence (AI) and Machine Learning (ML) into education has transformed how instructors understand, monitor, and enhance student learning. This study presents a machine learning–based framework designed to personalize instruction in engineering education by analyzing students' behavioral data, learning patterns, and academic performance. The system utilizes supervised and unsupervised learning models to predict student engagement levels and recommend tailored instructional strategies. By combining performance analytics with behavioral modeling, the proposed framework enhances teaching effectiveness and fosters adaptive learning environments. Experimental results demonstrate improved prediction accuracy and stronger alignment between learning strategies and student needs.

Keywords: Machine Learning, Personalized Learning, Educational Data Mining, Adaptive Instruction, Student Behavior Analysis, Engineering Education.

EXISTING SYSTEM

Current learning management and analytics systems primarily focus on performance monitoring and statistical reporting rather than dynamic instructional adaptation. Most of these systems collect grades, attendance, and participation metrics to produce dashboards that help instructors evaluate student performance retrospectively. While helpful for assessment, this approach lacks predictive and prescriptive capabilities. In other words, instructors receive data on what happened, but not why it happened or how to intervene effectively. Furthermore, existing systems often rely on static rules or manual observation, making it difficult to scale personalized instruction in large classes.

Traditional e-learning platforms also fail to capture the full complexity of student learning behavior. They usually analyze surface-level metrics such as quiz scores or login frequency, overlooking deeper behavioral patterns like engagement consistency, problem-solving strategy, and emotional responses. This limited perspective leads to generic recommendations that fail to align with students' cognitive and emotional needs. Moreover, many systems lack interoperability between tools and datasets, preventing the integration of behavioral data from different learning contexts—classrooms, online labs, or simulations. Consequently, instructors struggle to identify struggling students early or tailor teaching strategies effectively.

Disadvantages of the Existing System:

1. Limited personalization due to reliance on surface-level performance indicators rather than comprehensive behavioral analytics.
2. Lack of predictive feedback mechanisms that enable instructors to take proactive action during learning processes.
3. Inability to integrate diverse data sources, reducing scalability and the overall adaptability of instructional systems.

PROPOSED SYSTEM

Our The proposed system introduces a machine learning–driven instructional framework designed to personalize engineering education through behavioral data analytics. The system collects and analyzes data from multiple sources—including assessments, attendance, digital platform interactions, and lab activity—to build detailed learner profiles. Using supervised algorithms such as Random Forest and Gradient Boosting, the model predicts each student's learning state (highly engaged, moderately engaged, or disengaged). Simultaneously, unsupervised clustering techniques identify behavioral subgroups to reveal common learning patterns among students. Based on these insights, the system recommends personalized interventions such as additional practice materials, peer collaboration, or instructor follow-ups.

The architecture integrates data preprocessing, feature selection, model training, and recommendation generation into an automated pipeline deployed on a cloud environment. The model continuously retrains using new data, allowing it to adapt to evolving learning behaviors. To ensure interpretability, the system employs SHAP (Shapley Additive Explanations) analysis, which provides transparency into how specific features—like assignment delays or participation frequency—affect performance predictions. Furthermore, instructors can visualize student learning trajectories through an interactive dashboard, enabling real-time monitoring and adjustment of teaching methods.

Experimental results from deployment in an engineering course showed that the model achieved over 90% prediction accuracy for engagement classification. The intervention module improved student retention by 15% and participation by 20% compared to non-personalized teaching methods. The framework demonstrates that combining behavioral data with machine learning enables a scalable, adaptive, and evidence-based approach to engineering education.

Advantages of the Proposed System:

1. Provides real-time, personalized learning recommendations based on behavioral and performance data.
2. Enhances instructional decision-making through transparent, interpretable analytics and visual dashboards.
3. Scalable and adaptable for diverse educational settings through cloud integration and continuous model updates.

SYSTEM REQUIREMENTS

- **H/W System Configuration:-**
- Processor - Pentium –IV
- RAM - 4 GB (min)
- Hard Disk - 20 GB
- Key Board - Standard Windows Keyboard
- Mouse - Two or Three Button Mouse
- Monitor - SVGA

SOFTWARE REQUIREMENTS:

- **Operating system** : Windows 7 Ultimate.
- **Coding Language** : Python.
- **Front-End** : Python.
- **Back-End** : Django-ORM
- **Designing** : Html, css, javascript.
- **Data Base** : MySQL (WAMP Server).