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A Research on Machine Learning Driven Gamification Model for Personalized Education

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Abstract: Personalized learning has become an important approach in modern education as traditional learning systems often fail to address the individual needs, abilities, and learning pace of students. At the same time, maintaining student motivation and engagement in online learning environments remains a major challenge. The proposed system integrates personalized learning recommendations, adaptive difficulty adjustment, reward optimization, and engagement tracking into a unified web-based learning platform. Machine learning models analyse student performance, quiz history, learning behaviour, and engagement data to recommend suitable quizzes and courses according to the learner's skill level. The system categorizes recommendations into easier, same-level, and harder learning paths to support adaptive learning experiences.

To increase motivation and participation, the platform incorporates gamification features such as points, badges, levels, leaderboards, and achievement tracking. Student activities including logins, lesson views, and quiz attempts are continuously monitored to evaluate engagement and provide personalized feedback. In addition, a teacher analytics dashboard is implemented to help educators monitor student progress, identify at-risk learners, and analyse academic performance using predictive insights generated through machine learning.

Experimental evaluation and literature-supported analysis indicate that the integration of machine learning and gamification improves learner engagement, supports self-directed learning, enhances personalization, and contributes to better academic outcomes.

Keywords: Machine Learning, Personalized Education, Gamification, Gamified Learning, Gamification Model

I. INTRODUCTION

New generation of digital learning platforms makes learning available 24/7, whenever and wherever learners choose. In order to deliver interactive learning experience, many institutions and individuals utilize a number of technologies such as Learning Management Systems (LMS) and Massive Open Online Courses (MOOCs). The traditional e-learning environment often fails to respond to individual needs of learner, as most learning content is delivered in fixed and rigid environment.

Gamification within education has been proven to enhance engagement, improve learning outcomes, increase participation and create a more interactive studying environment through incorporation of game-like elements, for example, points, badges, leaderboards and rewards through videos, quizzes and assignments on Learning Management Systems (LMSs) and Massive Open Online Courses (MOOCs) and other online platforms. However, traditional methods of gamification fail to be personally tailored to each individual, providing all learners with the same set of challenges and corresponding rewards regardless of previous experience, ability and learning style.

To overcome the limitations of the traditional gamification approach, Machine Learning (ML) is integrated in order to create adaptive and personalized learning systems. The ML algorithm analyses the behaviour of students as well as their interaction with the system in order to identify their strengths and weaknesses as well as their individual learning style of learning. On the basis of this analysis, the system can then change the learning content as well as the level of difficulty of the challenges in order to offer the learner the most suitable content. The rewards and challenges can also be individualized in order to maximize the learner's motivation.

The proposed Machine Learning-Driven Gamification Model is designed to create an intelligent, education based system that makes use of the motivational factors of gamification and the adaptability of ML. By means of this approach students can be encouraged in an effective manner to better their learning results. The teacher too is supported. He or she is provided with the monitoring of learning results of individual students as well as of classes. He or she is also supported with respect to giving of due individual support to all students.

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II. LITERATURE REVIEW

The rapid growth of digital learning environments has prompted researchers to look into new methods for improving student engagement, motivation, and learning results. Gamification has become one of the most effective ways to boost learner participation by adding game elements like points, badges, rewards, leaderboards, challenges, and progress tracking to educational systems. Recently, researchers have also been combining gamification with Machine Learning (ML) techniques to create smart and adaptable learning environments.

Early studies mainly focused on traditional gamification models without personalizing or adapting to student needs. Study [2] examined gamification in computer science education using fixed game elements such as points, levels, badges, and feedback methods. The results showed notable improvements in student engagement, participation, and task completion rates. Similarly, Faiella and Ricciardi [3] carried out a thorough review of gamification in education and concluded that it boosts student motivation and academic performance. However, the study also pointed out issues related to over-reliance on external rewards and stressed the importance of good instructional design.

Several researchers explored gamification in Learning Management Systems (LMS) and collaborative learning settings. Study [4] implemented cooperative gamification elements in Moodle-based online courses and reported increased learner interaction, communication, and motivation. Likewise, studies [5] and [6] looked at how gamification affects student activity levels and self-reported learning success. Their findings suggested that gamified learning environments positively impact engagement, confidence, and learning effectiveness. However, these systems used fixed, rules-based gamification methods without adapting to individual needs.

Researchers also examined gamification in specialized educational areas. Study [11] proposed a gamified framework to teach usability heuristics in human-computer interaction education. This approach featured quests, rewards, and scenario-based tasks that enhanced learner understanding and engagement. Similarly, study [12] combined gamification with discovery learning to promote problem-solving and exploration, leading to higher motivation and active participation. Furthermore, studies [16, 19, 20, 21, 22] showed the effectiveness of gamification in areas like programming education, college-level learning, immersive digital environments, language learning, and LMS-based self-directed learning. These studies consistently noted improvements in participation, engagement, and learning outcomes, even though they lacked adaptive and smart features.

Long-term and adoption-focused studies further revealed the limitations of fixed gamification systems. Study [10] conducted a ten-year analysis and found that while gamification can maintain engagement over time, learner motivation may drop if game elements are not refreshed regularly. Similarly, study [23] analysed gamification adoption in higher education settings using the UTAUT framework. It highlighted that successful implementation depends on good teaching practices, teacher training, scalability, and organizational backing.

With progress in Artificial Intelligence and educational data analytics, researchers began incorporating Machine Learning techniques into gamified learning systems to provide personalization and adaptability. Study [1] presented a systematic review of personalized gamification in education, marking the shift from static models to intelligent adaptive systems using AI and ML. The review identified key techniques like learner profiling, adaptive rewards, personalized feedback, recommendation systems, and data-driven decisions in modern personalized learning systems. It also addressed significant challenges such as data privacy, scalability, and implementation issues.

Several studies proposed ML-based gamification frameworks for personalized education. Duggal et al. [7] developed an intelligent gamified learning framework using the ANFIS model for adaptive reward distribution based on student performance. Their results showed improvements in learner participation, engagement, and motivation. Similarly, da Luz et al. [8] conducted a systematic mapping study and concluded that Machine Learning greatly enhances gamified education by allowing for adaptive learning experiences and intelligent learner analysis.

Abbasi et al. [9] introduced a personalized gamified e-learning system based on learner motivation and personality traits. Their experiments showed that personalized gamification boosts academic performance, learner engagement, and LMS usage time more effectively than non-personalized systems. Additionally, Farhan et al. [13] studied ML-driven gamification in business contexts and found that adaptive rewards, predictive analytics, and personalized challenges enhance user engagement and retention. However, the study also raised concerns about algorithm bias, ethics, and data privacy.

Further advancements in adaptive learning systems were noted in studies [14, 15, 18, 24, 25]. Raftopoulou and Pallis [14] introduced personalized feedback dashboards using collaborative filtering and content-based recommendations to produce customized recommendations and progress insights for learners. Sikarwar et al. [15] explored hybrid Machine Learning approaches that combined collaborative filtering, content-based filtering, and deep learning to improve recommendation accuracy and real-time learning adaptation. Manoharan and Nagulapally [18] reviewed adaptive gamification algorithms that can adjust rewards, challenges, and feedback based on learner performance and preferences.

Study [24] proposed a personalized gamified learning framework using various supervised Machine Learning algorithms such as Random Forest, Decision Tree, Naïve Bayes, Logistic Regression, Support Vector Machine, K-Nearest Neighbours, and Multilayer Perceptron. These models analysed learner performance and engagement data to create

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customized learning paths and adaptive difficulty levels. Similarly, study [25] examined AI-driven gamification methods for fostering critical thinking through intelligent tutoring systems, learner modelling, adaptive feedback, and recommendation algorithms.

Overall, the literature shows that gamification boosts learner engagement, motivation, and academic performance. At the same time, Machine Learning improves personalization and adaptability in digital education systems. However, challenges like data privacy, scalability, ethical issues, and implementation complexity still exist. Therefore, we need intelligent Machine Learning-driven Gamification Models that can offer adaptive, personalized, and learner-centered educational experiences.

III. METHODOLOGY

A. Algorithms Implemented

1. Recommendation Algorithm: The recommendation algorithm is designed to provide students with personalized learning content based on their performance and learning activity. The system collects important learner data such as quiz scores, time spent on learning activities, and overall engagement level from the database. These features are then given to a pre-trained Machine Learning model to predict the most suitable difficulty level for each learner.
   Based on the prediction, the system recommends quizzes and courses categorized as easy, medium, or hard. To avoid repetition, previously completed quizzes are removed from the recommendation list. Finally, the system displays the most relevant learning content, helping students learn at a pace that matches their abilities and progress.

2. Gamification Algorithm: The gamification points algorithm rewards students based on their quiz performance. Points are assigned according to the quiz percentage, where every 10% score increase awards additional points. The system provides a maximum base score of 50 points, while students who achieve a perfect score of 100% receive an extra bonus of 20 points.
   This reward mechanism encourages learners to perform better and stay motivated throughout the learning process. By providing points and bonus rewards, the system promotes continuous improvement, active participation, and higher engagement in the learning environment.

3. Level Progression Algorithm: The level progression algorithm assigns student levels based on the total points earned through learning activities and quizzes. The system defines multiple levels such as Beginner, Learner, Intermediate, Advanced, Expert, Master, and Legend, where each level corresponds to a specific points range.
   The algorithm compares a student's total points with predefined level thresholds to determine the current level and the points required to reach the next level. This progression mechanism motivates students to stay engaged, achieve higher scores, and continuously improve their learning performance.

4. Badge Award Algorithm: The badge award algorithm uses a rule-based approach to reward students for their achievements after each quiz submission. The system checks predefined conditions such as completing quizzes, achieving perfect scores, and reaching specific point milestones to determine whether a badge should be awarded. Badges are awarded only once to each student to avoid duplication. This achievement system motivates learners by recognizing their progress and encouraging continuous participation and engagement in the learning platform.

B. Model Workflow for Personalization

Step 1: Data Preparation: The learning dataset is first cleaned and preprocessed to remove unnecessary data and extract important student features. The processed dataset is then stored in a structured format for machine learning training.

Step 2: Model Training: The prepared dataset is used to train two Random Forest models. One model predicts the suitable difficulty level for learners, while the second predicts the probability of student success. The dataset is divided into training and testing data to ensure proper model learning and validation.

Step 3: Model Evaluation: After training, the models are evaluated using classification accuracy to measure their performance on unseen data. The success prediction model achieved an accuracy of approximately 90.77%, showing effective prediction capability.

Step 4: Prediction and Recommendation: During system usage, student data such as quiz performance, learning time, and activity level is collected and provided to the trained models. Based on these inputs, the system predicts suitable difficulty levels and success probability, allowing personalized recommendations to be displayed through the learner dashboard.

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C. System Overview

The proposed platform is developed using the Flask framework following the Model-View-Controller (MVC) architecture. When the system starts, the database is initialized, required data is loaded, and the Machine Learning models are trained to support personalized learning recommendations and predictions. Users interact with the platform through a web-based interface.

The system supports two main user roles:

- **Student:** Students can access courses, study lessons, attempt quizzes, earn points and badges, track their progress, and receive personalized recommendations based on their learning performance and activity.
- **Teacher:** Teachers are provided with an analytics dashboard that displays student performance, engagement levels, gamification progress, and Machine Learning-based success predictions. This helps instructors monitor learner progress and provide timely support when needed.

IV. IMPLEMENTATION AND WORKING

A. End-to-End Flow

1. **Student Login:** The learning process begins when a student logs into the platform. After successful authentication, a user session is created, and the login activity is recorded in the database to monitor student engagement and activity.
2. **Course Browsing:** Students can explore the available courses displayed on the course page along with their respective difficulty levels. This allows learners to select courses according to their interests and learning level.
3. **Accessing Learning Content:** After selecting a course, students can study the available lessons and learning materials. The system tracks lesson views and updates the learning time to monitor student participation and activity.
4. **Quiz Attempt:** Students can attempt quizzes containing multiple-choice questions designed to evaluate their understanding and learning progress.
5. **Quiz Evaluation and Gamification:** Once the quiz is submitted, the system calculates and stores the quiz score in the database. Based on the student's performance, points are awarded through the gamification system. The platform also records quiz activity, updates learning statistics, and checks whether the student qualifies for any achievement badges.
6. **AI-Based Insights and Recommendations:** When students access the AI Insights section, the system analyzes their learning data, including quiz performance, activity level, and learning time. The trained Machine Learning models then predict the learner's suitable difficulty level and success probability. Based on these predictions, the platform recommends the most appropriate quizzes and courses to support personalized learning.

B. Gamification Engine

The gamification engine is designed to increase student motivation, engagement, and participation by integrating game-like elements into the learning platform.

I. **Activity-Based Rewards:** Students are rewarded for completing learning activities such as attending courses, viewing lessons, and attempting quizzes. This encourages active participation throughout the learning process.

II. **Automatic Reward System:** The platform automatically awards points, badges, and achievements whenever student's complete specific tasks, providing instant feedback and motivation.

III. **Points and Level Progression:** Students earn points based on their quiz performance and learning activities. As points increase, student's progress through different levels, helping them track their learning achievements.

IV. **Badge Achievement System:** Badges are awarded when students achieve predefined milestones such as completing quizzes, scoring high marks, or reaching certain point targets. These achievements motivate learners to continue improving their performance.

V. **Leaderboard System:** A leaderboard ranks students according to their total points, creating healthy competition and encouraging learners to stay engaged with the platform.

VI. **Activity Tracking and Storage:** All gamification activities, including points, badges, quiz attempts, and activity logs, are stored in the database to maintain accurate records of student progress and engagement.

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V. RESULT

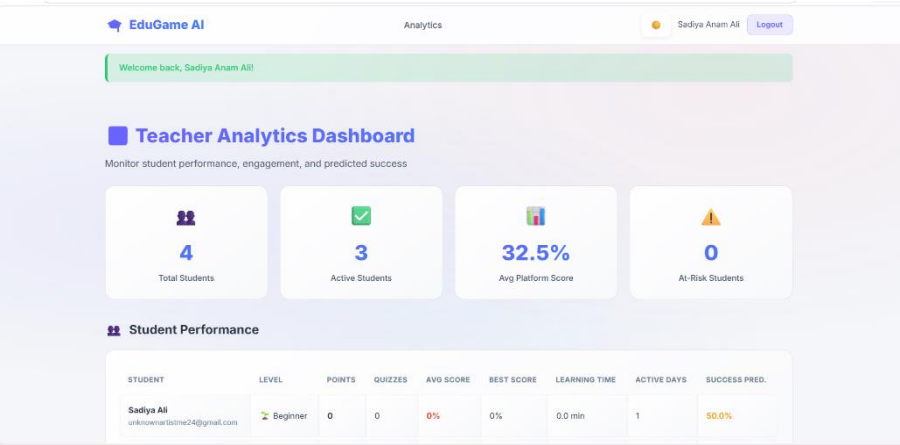

Fig. 1. Teacher Analytical Dashboard

The teacher analytics dashboard enables instructors to monitor student performance, engagement, and predicted learning outcomes using real-time analytics and Machine Learning insights.
Key Features Displayed:

- Total Students: Displays the total number of registered students.
- Active Students: Indicates the number of currently active learners on the platform.
- Average Platform Score: Shows the overall average performance of students.
- At-Risk Students: Identifies students with low engagement or performance who may require additional support.
- Student Performance Table: Provides detailed analytics of students.

The dashboard assists teachers in tracking learner progress, identifying struggling students, and making data-driven educational decisions.

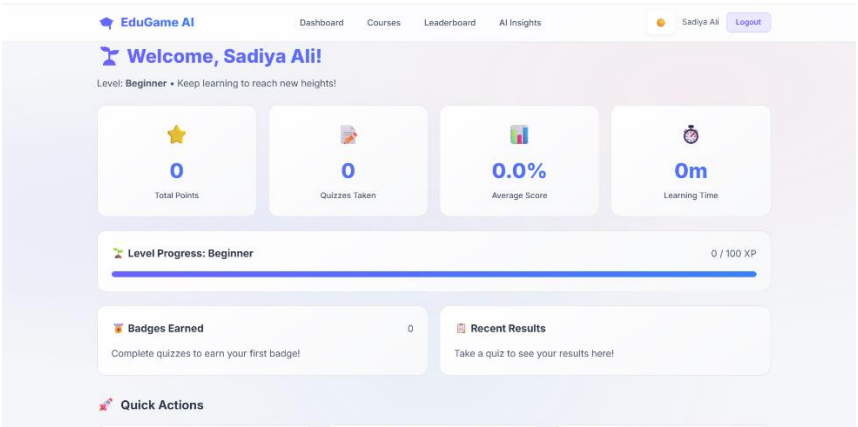

Fig. 2. Student Dashboard

The student dashboard provides learners with an interactive and personalized learning environment. After login, students can view their learning statistics, progress, and gamification achievements in real time.
It Displays the game elements like, Total Points, Quizzes Taken, Average Score, Learning Time, Level Progress Bar, Badges Earned, Recent Results, Navigation Modules

The dashboard helps students monitor their academic progress, remain motivated through gamification elements, and receive adaptive learning support.

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VI. CONCLUSION

This project presented a Machine Learning Driven Gamification Model for Personalized Education designed to improve student engagement, motivation, and learning performance in online learning environments. The proposed system combines gamification features such as points, badges, levels, and leaderboards with Machine Learning techniques to create a more interactive and personalized learning experience.

The system analyzes student performance and learning behavior to provide adaptive recommendations and suitable learning content based on individual capabilities. Gamification elements further encourage active participation, continuous improvement, and learner motivation.

The results show that integrating Machine Learning with gamification helps create a smarter and more engaging educational platform. In addition to improving the student learning experience, the system also assists educators in monitoring learner progress and identifying students who may need additional support. Overall, the proposed model contributes toward building an intelligent, adaptive, and learner-centered digital education system.

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