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Learning Curve and Performance Monitoring of Students in Online Education using Artificial Intelligence

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ABSTRACT

Online learning during the COVID-19 pandemic presents numerous challenges for students and institutions, including technical issues, low attendance, poor attention, and time management, all of which negatively impact academic performance. While modern tools can modify online content, monitoring academic progress without direct supervision remains difficult. To address this, performance monitoring and learning curve analysis are crucial for identifying struggling students and providing them with appropriate support. One potential solution is using predictive AI models to forecast students' future performance, providing instructors with insights about their learning progress and enabling them to take appropriate measures. This study proposes different AI, ML methods to increase students' learning curve, monitor their real-time performance, and offer instructors efficient online education with real-time insight during lectures.

Keywords **—** Online education, COVID-19 pandemic, predictive AI models, performance monitoring, learning curve analysis, academic performance.

I. INTRODUCTION

The COVID-19 pandemic had a negative impact on the entire educational systems, causing many educational institutions and universities to temporarily close in March 2020 due to a surge in COVID-19 cases. By April 2020, about 1.6 billion students across 200 countries, or 94% of the student population and nearly one-fifth of the global population, were affected by international educational shutdowns. These closures lasted an average of 41 weeks or 10.3 months and had significant negative effects on student learning, with expected long-term consequences for education and earnings. Additionally, education and official aid program budgets for education declined during the pandemic. Due to COVID-19, online learning has become widespread, but it lacks interaction between instructors and students. Thus, active monitoring of academic activities is necessary, and this study proposes methods to forecast student learning and performance.

The study employs various features to determine the best AI model for forecasting. The use of learning objectives and learning analytics to monitor student performance in e-learning environments became a necessity. By analyzing student interactions with learning management systems,

various tools aim to provide educators with valuable insights to improve the learning process. The proposed approach can aid teachers and researchers in evaluating student progress and supporting the promotion of effective teaching strategies [1]. Artificial Intelligence algorithms are used to monitor students' learning progress and classify the students who are at risk of unsatisfactory performance.

This study provides necessary information to the instructor to take corrective and preventive actions to monitor students' learning performance. With the given information, the instructor also extends additional support for the students having slow learning curve [9]. Many solutions are made to predict the performance by using a recommendation system which is powered by artificial intelligence techniques during the COVID-19. Several prediction models like linear regression, decision tree, random forest was used to achieve the optimal results. Among these models, the random forest algorithm was identified as the most effective for predicting the average using linear regression; which provides best prediction than others [10]. The importance of monitoring student performance in the modern, dynamic educational system and suggests that utilizing big data and machine learning can facilitate decision-making models for curriculum restructuring and record-keeping. By extracting data from various levels and domains of the education system, the models can make decision-making process more reliable and quicker. The other method is to collect data real time to analyze and predict the students' performance. For students, it will be easy to master the knowledge component if they know how many practice opportunities required for the mastery of the knowledge component. The student's learning efficiency can be improved by the method of learning curve based on grey models. These models put forward to determine the count needed for practice opportunity to master the knowledge component [12]. Student's academic evaluation techniques are used to show whether the student will succeed or fail and can provide guidance for future recommendations and assessments based on their performance [13].

II. LEARNING CURVE AND PERFORMANCE MONITORING

A. Learning Curve

Learning curves and performance monitoring are crucial aspects of optimizing any task or process, and AI has proved to be a powerful tool in this regard. By using AI algorithms, it is possible to analyze massive datasets and recognize patterns and trends that might not be instantly noticeable to human observers. This can help organizations to make more informed decisions about how to optimize their processes and allocate resources more effectively.

Furthermore, AI can be used to track individual performance over time, providing feedback and recommendations for improvement to help individuals reach their full potential. By leveraging the power of AI, organizations can gain a deeper understanding of their own performance and make data-driven decisions to improve their overall efficiency and effectiveness. Measuring the learning curve in online education can be challenging, but there are several techniques available to measure the learning curve and overall performance. One approach is to use online quizzes or assessments to track student performance over time. Another method is to use learning analytics tools to monitor student engagement with course content and identify areas where students may be falling behind.

Additionally, online discussions are useful resource for instructors to gauge student comprehension of course content and recognize areas where additional support may be needed. Finally, student feedback surveys are useful to record the students' feedback and classifying them as positive or negative feedbacks using the technique- SVM classifiers and create a performance outline for instructors. This can provide valuable feedback on course effectiveness and the quality of instruction, helping instructors refine their approach and improve learning outcomes [3].

Overall, the learning curve of students depicts the pace at which they gain knowledge and skills throughout a specific timeframe. It exemplifies the correlation between the extent of learning or advancement achieved and the corresponding time or effort expended in the process of learning.

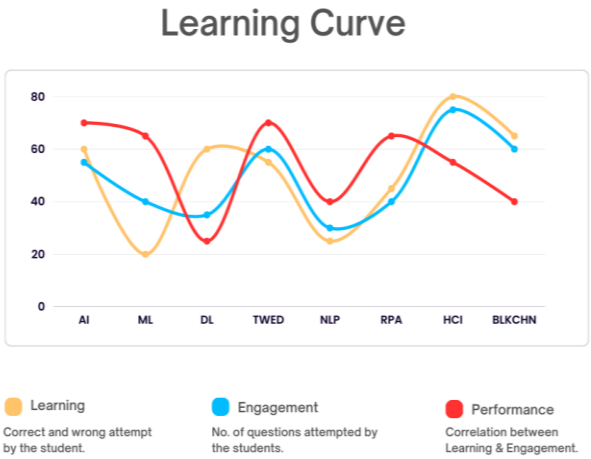

Fig. 1 Learning curve.

In Fig. 1 the learning curve emphasizes the students' performance in three different parameters: i) Learning, ii) Engagement, iii) Performance. The y-axis represents the scores for aforesaid parameters and the x-axis represents the subjects in which the scores has been collected. The yellow curve represents the learning score of the students, the blue curve represents the engagement of the students, and the red curve represents the performance of the students for various subjects.

B. Performance Monitoring

Performance monitoring is an essential aspect of online education, as it enables instructors to track student progress and adjust their teaching methods as needed. One common method of performance monitoring in online education is the use of learning management systems (LMS), which allow instructors to track student engagement with course materials and assess their progress. LMS platforms may also provide data on student performance in quizzes and assignments. The resulting performance data provides valuable insights into individual strengths and weaknesses. [1]. Another approach is to use analytics tools to monitor student behaviour, such as the amount of time spent on specific tasks or the frequency of interactions with course content that will help in the decision-making process [2]. This data can assist instructors detect areas where students may be facing difficulties and offer specific assistance. Online discussion forums and peer review activities can also provide valuable insight into student understanding of course material and enable instructors to increase the learning curve of the students.

Performance monitoring of students plays an important role in both online learning and blended learning. But, monitoring the performance of students in online learning is vital for assessing their progress, identifying areas for improvement, and offering timely support. Various methods and tools are commonly employed for this purpose such as Online assessments, discussion forums, personalized learning platforms, collaborative document editing platforms,

attendance tracking, and advanced analytics tools such as data analytics and learning analytics etc.

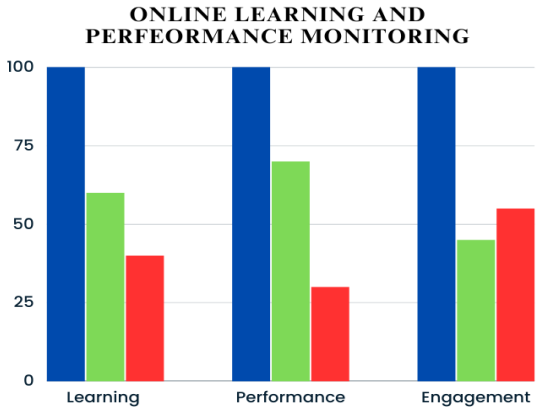

Fig. 1 Performance Monitoring.

In above Fig. 2, it explains students' learning, performance and engagement for a data sample collected and analyzed by the authors. The Blue color bar emphasizes the total number of students attending the online lecture, the green color emphasizes the positive or desired response and the red color shows the wrong or negative response. Ultimately, effective performance monitoring in online education requires a combination of tools and methods to provide instructors with a comprehensive understanding of student progress and performance.

C. Algorithm

Random Forest calculations can provide valuable insights into student performance in online education. This machine learning algorithm can analyze extensive quantities of data and detect patterns and trends in the behavior and academic achievement of students. [2]. By using Random Forest calculations, instructors can pinpoint areas where students are facing difficulties and adjust their instructional strategies to better support them. This can lead to improved learning outcomes and a more personalized learning experience for students. Ultimately, Random Forest calculations provide a powerful tool for performance monitoring in online education, enabling instructors to make data-driven decisions that optimize the learning experience for all students. The instructors also can get real-time insights of students' performance for better decision making.

D. Technique

The Random Forest algorithm uses an ensemble of decision trees to predict outcomes based on a set of input variables. In the context of performance analysis in online education, the algorithm can be utilized to forecast students' performance established on a range of variables such as engagement with course materials, performance on assessments, and demographic information. The mathematical formula for the Random Forest algorithm is:

$$y = f(X)$$

Where y is the predicted outcome (in this case, student performance), X is the set of input variables (such as engagement with course materials and demographic information), and f () represents the decision tree algorithm used to predict the outcome. The Random Forest algorithm combines several decision trees to create a more accurate prediction by reducing the risk of overfitting to the training data. The output of the algorithm is a probability estimate of the predicted outcome, which can be used to personalize the learning experience for individual students.

III. METHODOLOGY

This study proposes a unique method of taking quizzes during lectures to increase students' learning curve, monitor their real-time performance, and provide instructors with student's performance in online education with real-time insights. This will be helpful to track the performance of individual student as well as entire class. This method includes following:

A. Parameters

Learning: Analyzing the Learning data by referring to the correlation of right and wrong attempt of questions by the student to understand how attentively the student listening to the lecture and understanding what is been discussed in the lecture.

Engagement: Number of questions attempted can be a defined parameter for the engagement of the student in the online lecture. It is a correlation between the number of random questionnaires attempted vs total number of questions attempted by students in online lecture.

Performance: The student's attentiveness and attention Span in the lecture by collecting the data of Learning and Engagement parameters and check how promptly the student attempting the online questionnaire.

B. Data Collection

We perform this study to monitor the students' performance, learning and engagement during online lectures by collecting real time data through live questionnaire. Live data can be collected which will provide maximum accuracy to monitor the performance.

C. Data Processing

The collected data will be analyzed with defined parameter to study the performance, learning and engagement of the students by presenting it in graphs in the admin dashboard, enabling instructors to understand the real time performance of the students and also to get the graphical data on performance, learning, engagement and to take corrective measures to improve students' performance.

D. Data Storage

NoSQL data storage to store the data to ascertain scalability of the model in the real world and to improvise the system for functional optimization in real time application.

IV. OBSERVATIONS

AI can play a significant role in performance monitoring of students in online lectures by providing various insights to instructors and educators. AI can provide valuable insights into student performance in online lectures, enabling educators to tailor their teaching approach to meet the needs of individual students and improve learning outcomes.

Costa, Laecio et al.,[1] examines and employs learning features sets based on the learning objectives and interactions of the students in Learning Management Systems (LMS) to assess student performance, which benefits teachers in the evaluation process. The SapeS– 'Student Academic Performance Evaluation System' model was created to aid teachers in evaluating students' academic progress, using Ontology and Learning Analytics (LA) to support the process of e-learning evaluation. The model is divided into three sections: 1) Data Collection, 2) Data Processing and Analysis, and 3) Visualization of information.

Dr. M. Neelakantappa*1 et al.,[2] develops a system to support teachers in monitoring student behavior and making decisions based on collected data. The system provides strategic knowledge for students and automatically submit strategies to decision makers. The system captures student characteristics and analyzes data based on various types of movements, such as eye, oral, and head movements when a student is engaged in online classwork. It uses Modules-Client, Server, Shape predictor model, Face Detection, Face processing module.

Katragadda, Sharnitha et al.,[3] discusses a study that uses supervised learning techniques to perform opinion mining on student input regarding teaching and learning. The study employs a combination of artificial intelligence and natural language processing systems to analyze student feedback data collected from module analysis surveys.

Hamadneh, Nawaf N et al.,[4] proposes a method that combines statistical analysis and artificial neural networks (ANNs) recognize the crucial factors that influence student performance in a blended learning environment and predict their performance. The method considers factors such as the manner of learning (virtual or face-to-face), the percentage of live lecture attendance, the grades of midterm exams, and the percentage of assessments completed to evaluate student performance.

Nedeva, Veselina et al.,[5] identifies crucial factors affecting student performance and selecting an optimal machine learning algorithm to anticipate their academic outcomes. The study evaluated the effectiveness of four classification algorithms, namely Decision tree (J48), BayesNet (BN), Multilayer Perceptron (MLP), and Sequential minimal optimization (SMO), using the Weka open-source software to process the data.

Jiao, Pengcheng et al.,[6] establishes an artificial intelligence (AI) model to forecast academic performance in the context of online education. The study discovered that academic success primarily depends on knowledge acquisition, class participation, and summative performance, whereas prior knowledge is not a significant contributing factor.

Hooda, Monika et al.,[7] presents a study on the COVID-19 pandemic that caused significant disruption in higher education and resulted in a shift from traditional in-person teaching to online learning. Consequently, there have been changes in the methods of teaching, assessment, learning, and feedback, both in structure and nature.

Siddique, Ansar et al., [8] proposes the development of a fusion-based ensemble model that can forecast the academic performance of at-risk students in their early stages using their academic, social, family, and demographic characteristics. Early prediction can support students who face difficulty in achieving good grades and help improve their progress.

Khan, Ijaz et al.,[9] focuses on research that assess the proficiency of machine learning algorithms in tracking the academic development of students, and notifying instructors accordingly. To support this effort, three methods are employed: 1) Data preparation, 2) Experimental evaluation, and 3) Model implementation, which provide insights into students' progress and offer additional support to those experiencing difficulties. The study utilizes several techniques, including k-NN, ANN, naïve Bayes, and ML algorithms, with decision trees yielding an accuracy rate of 86%.

Tarik, Ahajjam et al., [10] During the COVID-19 pandemic, a smart recommendation system based on artificial intelligence techniques was deployed to anticipate academic performance. Various prediction models, such as decision trees with regression, random forest with regression, and linear regression, were utilized to attain the optimal outcomes. The linear regression-based random forest model was found to be the most accurate for predicting the average performance among all models.

According to Rastrollo-Guerrero, Juan L. et al.,[11] from the gathered data, supervised learning was found to be the most commonly used technique for forecasting student behavior due to its accuracy and dependability. Among the various algorithms, SVM provided the most precise predictions. In addition to SVM, other algorithms such as DT, NB, and RF were also thoroughly researched and demonstrated good outcomes.

Liu, Manqiang et al.,[12], presents a technique of predicted learning curve using grey models, which can estimate the number of practice opportunities required to achieve mastery of a knowledge component to improve student's learning efficiency.

Dengen, Nataniel et al., [13] proposes an evaluation technique to predict a student's likelihood of success or failure, which can serve as a guide for future recommendations and evaluations of their performance. The study employed the Naïve Bayes Classifier (NBC), which produced an algorithmic accuracy of 76.79% and a true positive rate of 44.62% based on quality training data of 80% and 90%.

Lim, Sunghoon et al.,[14] explores how student engagement affects academic outcomes in engineering education via MOOCs- 'Massive Open Online Courses'. The study uses correlation analysis to determine the connection between the student performance and student engagement. using authentic MOOC transcripts and discussion forum data to evaluate the effectiveness of the research.

Yabin, Huang,[15] analyzes advantages, limitations, and development of online education to increase the value of online courses and improve teaching effectiveness. It discusses the teaching strategies and provides guidance for optimizing teaching content.

Kim, Byung-Hak et al.,[16] introduces GritNet, a new deep learning algorithm that leverages bidirectional long short-term memory (BLSTM), designed to anticipate student performance by treating the issue as a sequential event prediction. The algorithm outperforms the standard logistic-regression-based method, as demonstrated by results from real Udacity students' graduation predictions and focuses on real-time prediction of student performance during ongoing courses, using a domain adaptation framework.

Kim, Byung-Hak [17]. Marbouti, Farshid et al.,[18] examines progress by exploring various prediction techniques to detect struggling students in the initial stages of a course through performance data gathered throughout the semester, with standards-based grading.

Kumar, NM Saravana [19] proposes an intelligent learning platform powered by AI, which encompasses intelligent tutoring and virtual reality. It involves AI features such as, recognition and pattern recognition, decision-making, conceptual reasoning, execution and sequential control, and problem-solving. The system assesses performance of the students through a combination of supervised machine learning techniques and knowledge-based systems.

Rivers, Kelly et al.,[20] explores the use of learning curve analysis to identify programming elements that students find challenging when learning Python. The study goes beyond traditional learning curve analysis by incorporating less structured data and provides new insights for when to teach new programming concepts to students.

Asiah, Mat et al.,[21] provides an overview of recent academic research on predicting student academic performance through the use of academic analytics. Numerous approaches have been suggested by different scholars to design effective performance tracking models that rely on student data, methods, algorithms, and tools such as regression, classification, and clustering techniques like DT, KNN, ANN, BN, SVM, among others.

Kexin, Liu et al.,[22] explores the "Before and After class" pedagogical approach in blended learning. Initially, the advantages and drawbacks of online education are highlighted through course selection and data analysis, and a strategy for enhancing them is presented. Subsequently, the teaching process is focused on the "Pre-class-in-class-after class" cycle.

Bujang, Siti Dianah Abdul et al,.[23] presents various machine learning techniques used to forecast first-semester course final grades, to improve predictive accuracy. The study compares six different machine- learning algorithms, including Random Forest (RF), Decision Tree (DT), Naïve Bayes (NB), K-Nearest Neighbor (KNN), Logistic Regression (LR), and Support Vector Machine (SVM) using a dataset of 1282 real student course grades. Additionally, it suggests a multiclass prediction model using two feature selection methods and oversampling Synthetic Minority Oversampling Technique (SMOT) to decrease misclassification and overfitting.

Orji, Fidelia et al.,[24] discusses methods to improve the engagement of students in online learning systems by using data-driven interventions. Objective data from an undergraduate course is used to determine student engagement using two machine learning approaches - Random Forest and Clustering. The results indicate that both engagement and assessment scores can predict academic performance, and these approaches identify interesting patterns in student engagement.

Jerry, Jummai E.,[25] discusses a study on instructor and student abilities in higher education using the didactic performance inter-behavioral model and also examines the impact of the pandemic on higher education.

Kiu, Ching-Chieh [26], analyzes the association between students' social activities, background and academic factors to predict their academic performance. The predictive modeling was done using supervised educational data mining techniques, such as Naïve Bayesian, Multilayer Perceptron, and Decision Tree, to forecast final grades, categorized into 2 and 5 levels. The findings show that student social activities and background are significant predictors of academic performance in the 2-level classification.

Supriyatno, Triyo et al.,[27] focuses various research methods including empirical, theoretical analysis, interview and questionnaire, to analyze the impact of Covid-19 on Islamic Higher Education (IHE). Main recommendations are 1) To organize training courses and 2) to offer comprehensive training programs on online teaching methods for non-pedagogical lecturers.

Carpio Cañada et al.,[28] discusses a new educational experience to address the limitations of formal learning. The study found students' motivation, academic achievement, and personal skills were enhanced by the educational experience.

Pei, Ying; Gang Li,[29] examines the use of data mining technology in a cloud environment. The data structure is analysed using a time series analysis model, and the high-dimensional phase space of data information flow in the cloud environment is reconstructed to extract association rules that can enhance the data mining algorithm.

Arashpour, Mehrdad et al.,[30] focuses on improving the accuracy of predicting student exam performance by combining two machine learning methods, artificial neural network (ANN), and support vector machine (SVM), with the teaching-learning-based optimizer (TLBO). This hybrid approach is designed to achieve more reliable predictions for both fail and pass classes and final exam marks.

Finata et al.,[31] presents a review examines the design of a student monitoring framework in higher education. The results

suggest that incorporating assignment points and quizzes into each class can be an effective approach to developing a student monitoring framework and to monitor the performance of students.

Lin, Po-Hsuan et al.,[32] provides an example of how artificial intelligence (AI) based robotic players can be used to enhance the teaching and learning of economics in an online asynchronous environment, to improve learning outcomes for students.

Ulloa-Cazarez, Rosa Leonor et al.,[33] introduces a Multi-layer Adaptive Neuro-Fuzzy Interference System (MANFIS) for forecasting student performance in online Higher Education settings. MANFIS prediction accuracy was compared against accuracies of Multilayer neural network, Radial Basis Function Neural Network and General Regression Neural Network. The result indicates that MANFIS is an alternative model to predict performance.

Li, Wenhao et al.,[34] investigates how the classroom atmosphere affects the academic performance and learning experience of students in virtual classrooms. A positive classroom climate promotes learning and a comfortable environment, while negative elements can improve learning duration and concentration. The findings suggest that instructors and designers can use this information to create a suitable climate that enhances students' academic performance and learning experience in an online environment.

Irish et al.,[35] investigates the impact of incorporating a post recommendation system mechanism in virtual course forums on students' competence to find relevant course material, forum interactions, and academic performance.

Tomasik, Martin J et al.,[36] discusses the theoretical, methodological, and practical aspects of formative assessment, focusing on data collection, model building, and feedback delivery. It also highlights the challenges involved in providing feedback in the classroom and implementing the evaluation system on a large scale.

Shin, Jinnie et al.,[37] introduces a deep learning model that predicts and optimizes the number of times a test should be administered by utilizing clustering methods. The clustering method provides meaningful insights into how test administration decisions relate to student performance profiles, aiding in decision-making.

Costa, Laecio Araujo et al.,[38] provides a review of the literature on the joint application of Computational Ontologies and Learning Analytics to perform academic evaluation of students. It provides researchers a comprehensive view of the current status of the association between Ontologies and Learning Analytics, as well as how they have been applied in a coordinated way.

Prabha, S. Lakshmi et al.,[39] discusses the use of the Learning Curve method in comparing the progress of rural and urban students in learning mathematics in an e-learning environment. It analyses the students' interaction data, including knowledge component level, time taken to solve a problem, and error rate, to identify learning progress. The results showed that the Learning Curve method is useful in visualizing students' performance in a granular level, which helped teachers and students to identify skill levels and progress.

Duldulao et al.,[40] focuses on the incorporation of a feature for parents to access their student's grades online, providing them with the ability to check their student's progress and performance anytime and from anywhere.

V. CONCLUSION

In conclusion, the paper aims to study, enhance and optimize the quality of data collected for monitoring student performance. Furthermore, this study proposes a unique method of taking quizzes during lectures to increase students' learning curve, monitor their real-time performance, and provide instructors with student's performance in online education with real-time insight. By implementing this approach, institutions can ensure that students are engaged and making progress, while instructors have the necessary tools to identify and address any weak points where students may be facing difficulties. Overall, the use of performance monitoring and predictive AI models have the potential to enhance quality of online education and ensure that students receive the support they need to succeed. Once the performance analysis was completed and the results were reported, the authors discussed the methodology they had developed for implementation.

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