

Review Paper

Using AI in Analyze and Improving Student Academic Performance

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Abstract

AI is the new evolution in this generation. It has led to improvement in all fields. It has to be used to improve education and academic outcomes. Instead of just letting students use AI generative models, users should have a comprehensive AI system that begins by creating a measurement process, monitors student performance, enhances the results, and suggests solutions. Data from studies were analyzed to evaluate students' work using AI and machine learning techniques. One study collected data from 80 students in a genetics course, observing their interpretations before and after receiving feedback (from AI, humans, or both). The quality of interpretations was assessed through quantitative analysis (using paired t-tests and descriptive statistics) and qualitative analysis (manual coding for accuracy, depth, and conceptual understanding). Additionally, an AI chatbot, based on the RAG model within the CustomGPT.ai system, was used to analyze students' responses

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to conceptual biology questions and provide immediate feedback to identify conceptual gaps. Several studies used data from school and university students to train machine learning models such as random forest, decision tree, SVM, KNN, Naive Bayes, and logistic regression. The data included academic and social characteristics such as attendance, study time, health, travel, and family background, and the model's performance was evaluated using metrics such as precision, recall, and F1 score. An artificial neural network (ANN) with multiple input characteristics was also used in one study, trained using the SGD algorithm, which demonstrated competitiveness compared to other models. One evaluation showed that the random forest model used to predict Python programming students' performance achieved an R^2 value of 0.55, indicating average accuracy.

Keywords: Artificial Intelligence, Education, Machine Learning, Students

1 Introduction

In recent years, education has changed dramatically with the integration of artificial intelligence (AI) tools into educational environments. The shift of educational institutions toward information-driven models has expanded AI from administrative support to intelligent lesson delivery, automated grading, learning assessments, and predictive representation of student work. With the rise of digital learning platforms, large amounts of student information—such as attendance, participation, and assessment grades—are easily collected, even online. This information provides unique opportunities for machine learning (ML) and educational data mining (EDM) to better understand learning activities and develop curricula (Yağcı, 2022)[8].

AI in Assessment and Feedback One of the earliest uses of AI in teaching is in the area of student assessment. According to González-Calatayud, Prendes-Espinosa, and Roig-Vila (2021)[10], AI tools are increasingly being used in automated marking, formative assessment, and work grading. Their systematic examination revealed that formative assessment is a widely used tool, enabling students to progress and support adaptive learning engagement. However, the review revealed a deficiency in many AI-based assessments, which require solid pedagogical foundations and rely on technical capabilities rather than alignment with educational goals. This deficiency creates a need to reconcile AI's computational skills with educational design, which is based on maximizing educational value (González-Calatayud et al., 2021)[10]. Feed-

back has also been affected by AI. Conventional feedback exhibits problems of latency and scalability, especially in large classes. With the advancement of large language models (LLMs), AI has been able to generate human-like, context-sensitive, and broad-ranging feedback. Against this backdrop, they emphasize Li and Botelho (2024)[9] emphasize the need for interpretable AI. They insist that existing AI feedback must be accurate, transparent, interpretable, and pedagogical. Their research demonstrated the need to design rules that align with the characteristics of effective teacher feedback—in terms of proficiency, effectiveness, and motivational support—while maintaining an ethical foundation against bias or data distortion (Li & Botelho, 2024)[9] . Artificial Intelligence in Prediction and Early Intervention Graduation in social intelligence is essential for predicting students’ academic performance. By examining past academic archives, demographic characteristics, behavioral information, and lesson assignments, AI can predict student outcomes and identify those who fail. Studies have confirmed the effectiveness of machine learning algorithms such as decision trees, support vector machines (SVM), random forests, logistic regression, k-nearest neighbors (KNN), Naïve Bayes, and neural networks in predicting grades and dropout risk (Kalpana, Arunmaran, Hanif, & Deebak, 2020; Yağcı, 2022)[7] & [8]. Improved Zhu (2024), a predictive design using the random forest algorithm to examine student work in a programming curriculum Python . The design accurately predicted academic outcomes and allocated influential elements, such as semester exam grades and assignment work. The study demonstrates the importance of predictive analytics in reaching at-risk students early (Zhu, 2024)[2]. allowing teachers to address the problem of academic failure early. As confirmed by Agarwal and Agarwal (2024)[6], artificial neural networks (ANNs) outperform their machine learning counterparts, with 97-98% accurate predictions when modified with specific learning rates, transfer functions, and moment coefficients. The findings demonstrate the tremendous potential of deep learning methods to provide accurate and scalable predictive tools in higher education (Agarwal & Agarwal, 2024)[6].

Integration with Learning Analytics Studies have focused on improving the accuracy of algorithms, Ouyang, Wu, Zheng, Zhang, and Jiao (2023)[11] argue , believe that the educational importance of artificial intelligence lies in its integration with learning analytics (LA). They conducted a quasi-experimental study on an online engineering curriculum that combined AI-based prediction applications with immediate feedback from learning

analytics, creating a closed-loop curriculum. This study improved student engagement, teamwork, and group acceptance. This approach is used in scientific intervention with prediction, as predictions are used to support the teaching plan and learners (Ouyang et al., 2023)[11]. The Broader Impacts of AI on Learning In addition to assessment and prediction, AI helps create learning curricula, motivation, and study practices for students. Mallillin (2024)[1] realized that AI-based adaptive learning systems help develop students' academic interests by offering personalized learning options, identifying struggling students, and providing timely assistance. These approaches strengthen motivation and enhance personalized learning styles, contributing to long-term academic success. Similarly, Rajeeva and Quraishi (2024) [5]also studied AI's ability to monitor student work, demonstrating its potential to provide real-time insights into work and early warning signs. Their study found that AI reduces administrative burden and increases teacher engagement and instructional support.

Challenges and Research Gaps Despite these advances, challenges remain. First, AI focuses more on accuracy than interpretability, creating a "black box" that reduces teacher and student confidence (Zhu, 2024)[2]. Second, there are ethical concerns related to information privacy, algorithmic bias, and clarity (González-Calatayud et al., 2021)[10]. Third, although deep neural networks perform with high accuracy (Agarwal & Agarwal, 2024)[6], they often fail to combine their predictions with educational objectives, limiting their practical value. Finally, most applications of artificial intelligence have focused on higher education, leaving room for research at other educational levels (Kalpana et al., 2020)[7].

2 Background

Artificial intelligence (AI) has become one of the most important fields in higher education, with applications ranging from predicting student learning outcomes, analyzing performance, and providing feedback, to building interpretable systems that take into account pedagogical and educational aspects. Research in this area can be divided into three main areas.

2.1 First, prediction:

This area focuses on using machine learning algorithms to predict student academic performance from educational data. Zhu (2024)[2] demonstrated that a random forest algorithm accurately predicted student performance in a Python programming course based on test scores, assignments, and attendance. Similarly, Agarwal and Agarwal (2024)[6] demonstrated that artificial neural networks (ANNs) outperform other algorithms, such as support vector machines (SVMs), logistic regression, and decision trees, achieving prediction accuracy of over 97% when specific learning rates and transfer function settings are used. This excellent accuracy supports the role of neural networks in predicting academic performance, especially in large and complex data sets. Other studies (Yağcı, 2022; Kalpana, 2020)[8][7] have highlighted the importance of educational data mining (EDM) in identifying student behavior patterns and identifying those at risk of failing or dropping out. This allows schools to implement early warning systems and take preventive measures before problems escalate. These studies emphasize that predictive methods mainly focus on quantitative accuracy and the ability to provide statistical information to support educational decision-makers.

2.2 Second Approach: Assessment Approach:

This approach focuses on using AI as a direct assessment tool, with the aim of providing personalized feedback in real time. Rajeena and Quraishi (2024)[5] demonstrated that AI can help teachers monitor student progress in real time, provide immediate reports on strengths and weaknesses, and suggest appropriate teaching strategies for each student. This approach goes beyond individual assessment to improve group interactions in virtual classrooms. In a study by Ouyang et al. (2023)[11] found that integrating predictive models with learning analytics improved student engagement, collaboration, and satisfaction with the learning experience in online courses. This suggests that assessment strategies should focus not only on predicting performance but also on improving the learning process through personalization and continuous interaction.

2.3 Third, interpretation and teaching strategies:

With the increasing use of artificial intelligence, the need for more transparent and interpretable systems increases to ensure acceptance and trust between educators and students. Li and Botelho (2024)[9] argued for the importance of developing systems based on large-scale language models (LLMs) that are not only technically sound but also pedagogically meaningful, interpretable, and capable of generating feedback consistent with teaching practices. This approach aims to bridge the gap between algorithmic accuracy and human needs in education. However, González-Calatayud et al. (2021)[10] concluded that much of the research is still focused on purely technical aspects, such as improving classification algorithms and accuracy rates, and lacks the foundations and pedagogical strategies necessary to integrate these tools into real-world classrooms. To fill this gap, we need to consider AI not just as a technical tool, but as part of a comprehensive educational system that aligns with pedagogical values and learning goals.

2.4 Comparative Summary:

Through this comparison, we can conclude that although the predictive approach achieves high accuracy in predicting student performance using advanced algorithms such as artificial neural networks and random forests, the application of these findings to classroom practice is still limited. Meanwhile, the evaluative approach focuses on using Artificial Intelligence as a tool to improve pedagogical interactions and provide personalized feedback, but its effectiveness requires further validation. The interpretive/pedagogical approach has raised important questions about the reliability and transparency of systems of Artificial Intelligence and has highlighted the need to improve the pedagogical aspects of these tools.

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3 Related Works

3.1 Artificial Intelligence (AI) Towards Students' Academic Performance

Artificial Intelligence analyzes student performance by defining their education needs and enhancing academic results. Also, AI measures student attitudes from learning, encourages their motivation, and uses adaptive learning techniques to guide them. This results in improving and enhancing learning performance.

Data collection:

- Mixed-methods approach with focus group discussions used.
- Random sampling of 100 respondents based on criteria.

3.2 Prediction and Analysis of University Student Performance Based on Machine Learning

The student analyzes student performance using a random forest algorithm to predict the learning outcomes from learning data from 395 students in a Python programming course. The model achieves great results. R^2 of 0.55, MAE of 3.61 points, and RMSE of 4.68 points, indicating accurate predictions. Early intervention and curriculum improvements can achieve by including the the score of the 2nd unit test, the 4th unit test, and average homework scores in Key predictors influencing performance. Data collection:

- The study collected learning data from 395 students.
- These students were enrolled in a Python Programming course.
- The course was offered by Chongqing University of Posts and Telecommunications.

Machine Learning Model: The study developed a predictive model based on the random forest algorithm

Machine Learning Evaluation:

- The model's performance in predicting student performance was evaluated using several metrics.
- The evaluation results indicated the following: R-squared (R^2) value: 0.55 Root Mean Squared Error (RMSE): 4.68 points Mean Absolute Error (MAE): 3.61 points

In summary, the research utilized a random forest model and assessed its accuracy using

R^2 , RMSE, and MAE to determine its effectiveness in predicting student performance.

3.3 The end of multiple choice tests: using AI to enhance assessment

AI can analyze student weaknesses by evaluating the answer explanation in formative assessments, such as multiple-choice questions. AI tools such as Dewey provide instructors with real-time feedback on student thinking by identifying misunderstandings and misconceptions. This analysis discloses the gaps in understanding, such as incorrect assumptions about gene dosage or the role of transcription factors, allowing educators to tailor their instructional strategies and address specific areas where students struggle, in the end enhancing learning outcomes.

Data collection:

- Students were asked to explain why they chose their answers and why 'wrong' choices are wrong.
- A discipline-trained AI-based bot analyzed these explanations to identify missing or misapplied concepts and principles.
- Questions from the Biology Concepts Instrument (BCI) were used in a small 'proof of concept' study. Machine Learning Model: The study leverages a specialized AI chatbot built on a RAG model within the CustomGPT.ai system to provide actionable feedback on student thinking in the context of formative assessments. This allows for rapid and informative analysis of student explanations, addressing the limitations of traditional multiple-choice tests

Machine Learning Evaluation:

The evaluation of the machine learning model (CustomGPT.ai system, specifically the Dewey chatbot) in this study was conducted through a "proof of concept" approach, focusing on its ability to analyze student explanations and provide actionable feedback. This evaluation aimed to demonstrate the system's utility in enhancing formative assessment beyond traditional multiple-choice tests.

3.4 Leveraging Artificial Intelligence for Student Performance Monitoring

AI analyzes student performance by leveraging machine learning algorithms, natural language processing, and data analytics to identify patterns and trends that traditional assessment methods may overlook. It provides real-time feedback and personalized learning experiences, enabling early identification of struggling students for timely interventions. AI tools, such as adaptive learning platforms and AI-driven tutoring systems, collect and analyze performance data, enhancing educational outcomes and reducing the administrative burden on teachers, allowing them to focus more on instruction and student engagement.

Data collection:

- AI tools collect and analyze student performance data.
- Data analytics provides personalized learning experiences.

Machine Learning Model: Leverages algorithms to analyze student performance data.

Machine Learning Evaluation:

- Identifies patterns in student performance data.
- Enables early intervention for struggling students.

3.5 Predicting Student Academic Performance Using Neural Networks: Analyzing the Impact of Transfer Functions, Momentum and Learning Rate

Artificial Intelligence (AI) contributes to improved academic performance by analyzing students' learning outcomes, identifying specific learning needs, and providing personalized instruction. The technology measures learning attitudes, enhances student motivation, and guides students through adaptive learning strategies, ultimately leading to improved learning experiences and academic performance.

Agarwal, M., & Agarwal, B. B implement ANN using: 482 input nodes, 2 output nodes, 1 hidden layer, 100 epochs, Activation functions: Sigmoid, ReLU, Softmax Training algorithm: Stochastic Gradient Descent (SGD) [6]. Data was collected from 689 undergraduate students at IP University through Google Forms. Relevant features were

identified via a preliminary survey of 150 stakeholders, covering psychological, educational, and background factors. Examples of features: attendance, parental education, number of siblings, language, assignments, travel time, and health status. To evaluate the model, the Data was split: 70% training / 30% testing And used for Evaluation the following metrics:

Accuracy

Recall

Precision

F1 Score

AUC

ANN performance was compared with other models: KNN, SVM, Decision Tree, Naive Bayes, Logistic Regression, and Random Forest. The advantage of this study is that. It used artificial intelligence, specifically neural networks, to predict student grades with very high accuracy (98%). That can identify struggling students early, before failure occurs. And tested various configurations like learning rate and momentum to optimize performance. Also, compared many algorithms like SVM and Decision Trees, and neural networks came out on top, used real data from 689 students, giving credibility to the findings, and helping teachers create personalized learning plans for each student. The limitation of this research is that the dataset of students is not large, with fewer than 700 students. That cannot lead to generalizing the result. The research omits some factors like students' social interactions, interpersonal skills, and academic engagement, which might indicate a gap in the understanding of all variables that affect student outcomes.

3.6 Student Performance Analysis using Machine Learning

Artificial intelligence (AI) can analyze the students' weaknesses by evaluating the explanations of the selected answers in formative evaluations, such as multiple option questions. To identify erroneous and misunderstood concepts, AI herramientas like Dewey provide teachers with quick and useful feedback on the students' thoughts. This analysis reveals gaps in understanding, such as erroneous concepts regarding genetic expression or the function of transcription factors. This allows teachers to adjust teaching strategies and address specific problems with students who are experiencing difficulties, thus improving learning outcomes.

Student performance data (academic data) were collected using a cluster-linked approach from the Learning Cup 2006: Student Education Database. Therefore, the dataset was pre-filtered and free of skewed data. Data on absence, study time, travel time, family size, and health status were included. Models such as Random Forest (RF), Decision Tree (DT), and Logistic Regression (LR) were applied. The evaluation methods used were based on machine learning and multivariate analysis strategies and were evaluated using performance tools, excluding failures due to high prevalence, G1/G2 quality charts, and gender-based education statistics. No precise details were provided regarding numerical evaluation metrics or data split ratios.

3.7 Educational data mining: Prediction of students' academic performance using machine learning algorithms

In this study, we present an understandable AI system based on a large-scale language model (LLM) aimed at improving feedback in education. The system classifies the type of feedback and compares human-generated responses with AI-generated responses. The model improves the relevance of educational feedback by providing structured, clear, and personalized guidance to students. However, it is still a conceptual approach and further implementation in real classrooms is needed to validate its effectiveness.

The data was obtained (scraped) from the UCI Machine Learning Repository and covers two Portuguese secondary schools and includes a wide range of demographic, social, and related information such as grades, absences, study time, etc. Algorithms used: Decision Tree, Random Forest, Support Vector Machine / SVM, K-Nearest Neighbors / KNN, Naive Bayes, Logistic Regression. We split the dataset into training and test sets, and used cross-validation for reliability. The evaluation metrics we considered are accuracy, recall, precision, and F1 score.

3.8 Bridging Human and AI Explanations to Support Students' Revisions of Open-Ended Responses

This systematic review of 22 studies examines the application of artificial intelligence in educational assessment. It highlights that AI is primarily used for formative and automated assessment. Despite its usefulness, the study suggests that current AI tools

exhibit a notable lack of pedagogical logic, suggesting the need for deeper integration with principles of instructional design.

3.9 Artificial Intelligence for Student Assessment: A Systematic Review

A study combines AI-based predictions with real-world classroom learning analytics. Using a similar experimental design, it shows that incorporating this design increases student engagement, collaboration, and satisfaction in the classroom. This study provides practical evidence of how AI can be integrated into everyday learning and a strong example of the use of AI in the education sector.

Table 1: Synthesis Matrix for Literature Review

Study	Authors	Year	Key Findings/Results	Methodology	Limitations	Advantages
Artificial Intelligence (AI) Towards Students' Academic Performance	Mallillin	2024	AI enhance student learning and measures student. Attitude	Quantitative research use to Measure and detect the related factors to enhance academic performance Qualitative research is used to evaluate and analyze the AI Enhance the academic performance of students among the respondents.	The study uses a mixed-methods approach (focus groups + survey), but lacks a control or comparison group to assess the effectiveness of AI interventions versus no intervention.	Targets specific learning needs for improved outcomes. And Enhances motivation and attitudes toward learning

Prediction and Analysis of University Student Performance Based on Machine Learning	Xiaobo Zhu	2024	The model provide a good result for student performance $R^2 = 0.55$, RMSE = 4.68 and MAE=3.61. analysis predict the learning difficulties and curriculum enhancement.	Predictive model based on random forest that analyze student performance specifically on python course.	Limited amount of data used in the research. Not all indicators have been used in this study such as classroom interaction frequency and homework completion time	the study's advantages lie in its practical applications for identifying at-risk students, refining educational programs, and elevating teaching standards.
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The end of multiple choice tests: using AI to enhance assessment	Klymkowsky	2024	Dewey delivered a detailed analysis for students and define the miss understand concept by allowing student to explain why they choose this answer. Then the AI bot “Dewey analyze the student answers and identify misconceptions and missing knowledge	Develop a AI Bot	The current answer is unsure student understanding. Training Data: Dewey’s accuracy depends on its curated knowledge base. Adoption Barriers: Instructors must embrace formative assessment and redesign courses around feedback. Expansion Needed: Larger trials across diverse subjects and student populations.	Incorporating AI-analyzed formative assessments enhances the depth of understanding by guiding instructors on how to address misunderstandings, ultimately leading to improved learning outcomes and a more accurate assessment of student comprehension compared to traditional multiple choice tests.
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Data-Driven Insights: Using AI to Analyze Student Performance in English Language Courses	Adlin Jerusha	2024	The study result in enhancing the performance by analyzing the the factors such as motivation and resource availability using AI. This indicates that understanding these interconnections can lead to enhance educational strategies.	The study use SPSS for quantitative analysis to study the increase in student performance in English course as a second language.by using both descriptive and inferential statistics to analyze survey data that collected from student according to their study habits, demographics and the others factors.	The study focus on English courses student only, so the generalization in this research is limited	AI enhances personalized course development for students. Identifies key factors influencing student success and performance.
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Leveraging Artificial Intelligence for Student Performance Monitoring. International Journal of Research Publication and Reviews&Rajeena, M.,	Quraishi	2024	The study focus on detecting the positive effect of AI on students outcomes and how can AI provide a real time feedback. The research found that how can AI access just handle simple management task to analyze student performance and enhance student outcome.	The study review existing researches in AI tools used in effectiveness in monitoring and evaluating student performance. Which include examining adaptive learning platforms, AI-driven tutoring systems. That will lead in detecting struggling students which will lead to enhance education outcome.	The study discuss the ethical issues and challenges related in Using AI. including privacy issues which is counted as main limitation in using AI in analyzing student performance.	Provides real-time feedback and personalized learning experiences. Enables early intervention for struggling students.
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Predicting Student Academic Performance Using Neural Networks: Analyzing the Impact of Transfer Functions, Momentum and Learning Rate&Agarwal, M.,	Agarwal	2024	The study get great result in prediction student performance. The prediction accuracy is 98% using artificial neural network. As a comparative analysis of various Machine Learning Algorithms the result the ANN achieve Better result than SVM, KNN, NB, DT and others ML algorithms indicate that ANN has the potential to improve student performnce.	The study utilizes Artificial Neural Networks (ANN) as the primary method of analyzing student performance. The study used SVM DT, KNN,LR,NB as comparative research to show the superiority of ANN with a 97% accuracy rate.	The dataset of students is not large which is less than 700 student. That can not lead to generalize the result. The research omit some factors like students' social interactions, interpersonal skills and academic engagement which might indicate a gap in the understanding all variables that affect student outline	Why is it important? This research used artificial intelligencespecifically neural networksto predict student grades with very high accuracy (98%). Can identify struggling students early, before failure occurs. Tested various configurations like learning rate and momentum to optimize performance. Compared many algorithms like SVM and Decision Trees, and neural networks came out on top. Used real data from 689 students, giving credibility to the findings.
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Student Performance Analysis using Machine Learning. International Journal of Innovative Technology and Exploring Engineering	Kalpana et al.	2020	Random Forest model to predict student outcomes using assessment data	Machine Learning (Random Forest)	No live classroom application; lacks qualitative evaluation	The goal is to help teachers detect students who need support early, based on their grades and classroom behavior. Provides early warning system for at-risk students. Combines insights from psychology, education, and computer science. Improves communication between teacher, student, and administration. Helps institutions understand student levels and improve academic programs
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Educational data mining: Prediction of students' academic performance using machine learning algorithms	Yağcı	2022	Midterm scores predict final grades with 70–75% accuracy	ML (SVM, RF, NB, KNN)	Simple features; lacks full behavioral data	What does it do? Builds a model to predict final exam grades based on midterm scores and department/faculty data. Used real data from over 1800 students, ensuring robust and realistic outcomes. Tested multiple algorithms (Random Forest, Nave Bayes, etc.) and identified the most accurate. Helps detect at-risk students early through predictive insights. Supports smart learning environments driven by data analytics.
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Bridging Human and AI Explanations to Support Students' Revisions of Open-Ended Responses. Proceedings of the 17th International Conference on Educational Data Mining (EDM 2024),	Li & Botelho	2024	Develops explainable feedback using LLMs; taxonomy of feedback types	LLMs + Text Analysis	Still theoretical; requires real classroom deployment	Intelligent Feedback Systems (Li & Botelho, 2024) Development of explainable systems that provide human-like, precise feedback using large language models like GPT Classification of feedback types according to specific educational objectives Analysis of student-AI interactions to improve educational tools Providing individualized feedback in large classrooms, enhancing educational equity.
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AI for Student Assessment - Systematic Review	González-Calatayud et al.	2021	AI mostly used in formative assessment and auto-grading	Review of 22 studies	Lack of educational/pedagogical grounding	This isnt an experimental study but a review of 22 previous studies on AI-based student assessment. Highlights the use of AI in formative assessment and instant feedback. Discusses differences between AI-enabled and traditional education. Stresses the need to train teachers on using AI pedagogically, not just technically. Offers useful recommendations for schools and universities aiming to adopt AI in assessment.
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4 Conclusion

To guide students in their academic path, Machine learning models can analyze student performance and provide suggestions. In previous studies, a different Machine learning model has been used. For example, the Random Forest Algorithm, which is used to analyze student performance as in (Xiaobo Zhu 2024) [2], is used to analyze student performance in a Python programming course. An AI chatbot built on a RAG has been used by (Klymkowsky 2024)[3] to provide actionable feedback on student thinking in the context of formative assessments. ANN has been used by (Agarwal, M., & Agarwal, B. B., 2024)[6] and compared with SVM, Decision Trees, and other Machine learning models, and provides a better result. The limitation of the findings was mostly about the amount of data, which needs to be increased. For future work, we can depend more on ANN as it was the best for analyzing MCQ questions. And can use NLA for analyzing the student's explanation for each answer.

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