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Exploring Software Infrastructures for Enhanced Learning Environments to Empowering Education

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Abstract

Recently, the education sector has undergone a notable change due to the incorporation of technology, resulting in the emergence of Educational Technology (EdTech). This new trend has completely transformed the learning process for students, teaching methods for educators, and operations of educational institutions. Due to EdTech, education has become simpler to access, engaging, and efficient, providing customized and diverse learning experiences. This article explores into the significant influence of EdTech on the field of education and the promising opportunities it offers for the future. EdTech has become a significant enabler, allowing institutions to meet evolving student needs and cultivate new skillsets without being limited by geographical barriers. EdTech integrates digital and technological media with conventional methods of instruction to enable various forms of learning, offering adaptability, enhancing engagement, and providing high-quality educational solutions. EdTech tools empower educators to track student engagement, encourage interactive and creative learning experiences, and stand for human-centred education focusing on

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critical thinking, innovation, and entrepreneurial activity. Exploring deeper relationships between educational data as well as predicting how well students do in school has been made possible through educational data mining. Presented is a novel model utilizing machine learning computational methods to forecast the EdTech for the students by using their midterm exam results. Various machine learning algorithms were assessed and providing the EdTech for improving their performance in final exam. This study comprehensively examines different EdTech technologies and recommend a unified model that could serve as a solid framework for classroom teaching.

Keywords: Education, Technology, Ed-Tech, Review, Machine Learning Techniques.

1 Introduction

With the ever-changing educational environment, the incorporation of ICT (Information and Communication Technology) is becoming more common, providing exciting chances to improve educational systems. Exploring the various effects of ICT on the quality of education, this study will uncover both its advantages and obstacles. This study explores into the relationship between ICT and educational excellence in (Lim et al., 2020; Abdul-Hussein & AL Rikabi 2023) emphasize the importance of securing image data transfer and storage for cloud communications in education, demonstrating ICT's transformative potential. In (Adu & Mireku 2016), the focus is on the significant impact of ICT on enhancing environmental education, highlighting its extensive effects on teaching methods. In addition, Al-Malah et al., (2023) explain the impact of 5G networks on educational technology, leading to improved learning opportunities.

Amutha (2020) adds to our knowledge by investigating the overall effect of ICT on educational quality and offering insightful information about how it will influence education going forward. Bhasin (2012) explores the utilization of ICT in education, explaining how technology can enhance educational experiences. The foundational works set the stage for our research, helping us navigate the complex connection between information and communication technologies and educational quality.

As we explore into this research endeavor, we are driven by a series of core inquiries. Could you explain how ICT impacts teaching methods and student learning in educational environments, as discussed (Lim et al., 2020) Exploring the challenges and opportunities that come with incorporating ICT into educational systems, (Sangrà & González-Sanmamed 2010; Tolani-Brown et al., 2021) provides light on the importance of ICT in creating inclusive and accessible educational settings, ultimately aiming to develop strategies for promoting fair learning environments.

The study focuses on predicting students' academic performance only on their grades, without considering any demographic or socio-economic information. The study focused on creating a novel model using machine learning algorithms to offer optimal educational technology for undergraduate students preparing for their midterm exams, as well as for the faculty and department associated with the students. Determined the classification methods with the greatest success rate in predicting students' academic achievement using the machine learning classification methods. These models will facilitate the creation of instructional measures and novel strategies to enhance students' academic performance. By conducting assessments after each midterm, the number of students at risk of failure can be minimized (Stefanov 2018).

2 Related Works

2.1 Review on Analysing the Current ICT Integration

Within the education sector, the use of Information and Communication Technology (ICT) has become more common, significantly impacting the way teaching and learning are conducted. (Adu & Mireku 2016) stress the significant impact of ICT on enhancing environmental education instruction, underscoring its ability to improve teaching methods. In addition, (Sangrà & González-Sanmamed 2010) highlight the significant influence of ICT on educational procedures in elementary and secondary schools, stressing its capacity to promote engaging and interactive learning environments. Al-Malah et al., (2023) enhance our understanding by explaining how the use of 5G networks can improve educational technology, opening up possibilities for new teaching approaches. Abdul-Hussein & AL Rikabi (2023) emphasize the importance of secure storage and transfer of image data for cloud communications, highlighting the crucial role of ICT infrastructure in enabling smooth educational experiences. This section provides helpful perspectives into the possibilities as well as obstacles related to leveraging technology for learning enhancement by evaluating the current state of technological integration in educational systems (Hasas et al., 2024).

2.2 Review on Effects on Learning and Teaching

Exploring the influence of ICT on teaching methods and educational achievements is a key aspect of ICT has a complex impact on teaching methods and student learning results, which remains a prominent topic of research and debate in the education sector. In (Zabriskie et al., 2019), they offer valuable insights on the role of ICT in enhancing access to quality education, especially in underdeveloped areas of the global south. This contributes to reducing educational disparities and promoting inclusivity worldwide. In addition, (Kadhim et al., 2023) provide a detailed analysis of the impact of combining mobile wireless networks and IoT on online education in engineering colleges. They emphasize the transformative power of ICT in changing educational delivery methods and enhancing the educational experiences of students in specialized areas. In addition, (Bhasin 2012; Yuting et al., 2022) provide strong evidence in favor of incorporating ICT into teaching and learning methods. They demonstrate how technology can be used to develop interactive and customized learning environments that cater to the unique needs and preferences of each student. Similar to the research conducted (Betaraya 2020), it highlights the crucial significance of tackling the obstacles and shortcomings linked to ICT in education. It stresses the necessity for well-planned interventions to improve the efficiency and effectiveness of educational methods. This section goes into the assessment of ICT's effect on teaching and learning to enhance understanding of how technology can enhance educational experiences and boost student outcomes. It is expected that people, specifically physical education teachers, will be more creative in choosing new technologies that are beneficial, successful, and effective. That's why Android-based tools have been made so that teachers can do their jobs better, especially when it comes to gathering information on students' physical education capabilities (Santoso et al., 2023).

2.3 Review on Achievement in Technological Innovations within Education

Utilizing ICT in education is crucial for improving learning outcomes and equipping students for the digital era. The literature highlights the significance of cybersecurity training for promoting digital competence and online security among students (Fazil et al., 2023). Furthermore, studies emphasize the significant impact of the Internet of Things (IoT) on changing educational methods and enabling engaging learning opportunities (Hakimi et al., 2024; Hasas et al., 2024). Furthermore, research

highlights the benefits of integrating ICT into teaching methods, student achievements, and academic results (Hakimi et al., 2024). The comprehensive research highlights the various advantages of ICT in education, such as increased access to educational materials and improved communication and participation in learning activities. These studies offer helpful information for teachers, officials, and individuals interested in optimizing technology-enhanced learning environments by exploring various aspects of ICT integration.

2.4 Review on Machine Learning Methods

Reviewing past studies on predicting academic success reveals that various machine learning algorithms have been utilized, such as multiple, probit, and logistic regression, neural networks, as well as C4.5 and J48 decision trees. Random forests (Park et al., 2019) genetic programming (Zabriskie et al., 2019) and Naive Bayes algorithms (Xing et al., 2015) have been employed in recent research. These models achieve remarkably high levels of prediction accuracy. To accurately predict the academic achievement of students, a thorough comprehension of the variables and characteristics influencing student outcomes is essential in (Ornelas & Ordonez 2017). In this study (Alshanqiti & Namoun 2020), they analysed 357 articles focusing on student performance and examining the effects of 29 different features. The features primarily focused on psychomotor skills, including course and pre-course efficiency, participation by students, and student demographics like gender, secondary school performance, and self-regulation. Nevertheless, the dropout rates were primarily impacted by motivation among students, behaviours, interpersonal and economic problems, insufficient progress, and changes in careers. Based on the literature review, enhancing education quality involves predicting students' academic performance and providing support to those at risk. Academic performance prediction in literature involves analysing different factors such as digital footprints left by students online, socioeconomic background, learning skills, habits of study, social support perception, inspiration, and academic performance characteristics, among others (Hellas et al., 2018; Fernandes et al., 2019; Rubin etal., 2010; Waheed et al., 2020; Xu et al., 2019; Rizviet al., 2019; Garcia-Gonzalez & Skrita 2019; Rebai et al., 2020; Costa-Mendes et al., 2020). Most models developed in these studies typically achieve prediction accuracy between 70 to 95%. However, gathering and analysing such a wide range of data is time-consuming and demands specialized expertise. In a study (Hoffait & Schyns 2017), it was proposed that gathering extensive amounts of data can be challenging, and socio-economic data may not be essential. In addition, demographic or socio-economic information may not always accurately predict failure prevention (Bernacki et al., 2020). In (Park et al., 2019), they recommend a new way to find a class-level hiding method used in Android apps in this study. A paragraph vector is used by the proposed approach to vectorize the decompiled coding of each type of Android app. The result vectors are then sent to a machine learning algorithm, to find out which hiding method is used for each class.

3 Methodology

Education and machine learning are closely related fields. ML algorithms examine how students interpret and interact with the information provided to them. It assists the system in guiding users to revisit certain learning points or progress further. ML also assists teachers in individually monitoring and tracking the learning process. When comparing ML to traditional classroom methods, the goal moves from simply delivering the course material to ensuring a deeper understanding of the information. The ML methodology utilized to develop learning skill in the field of Education. ML based EdTech is shown in Figure 1.

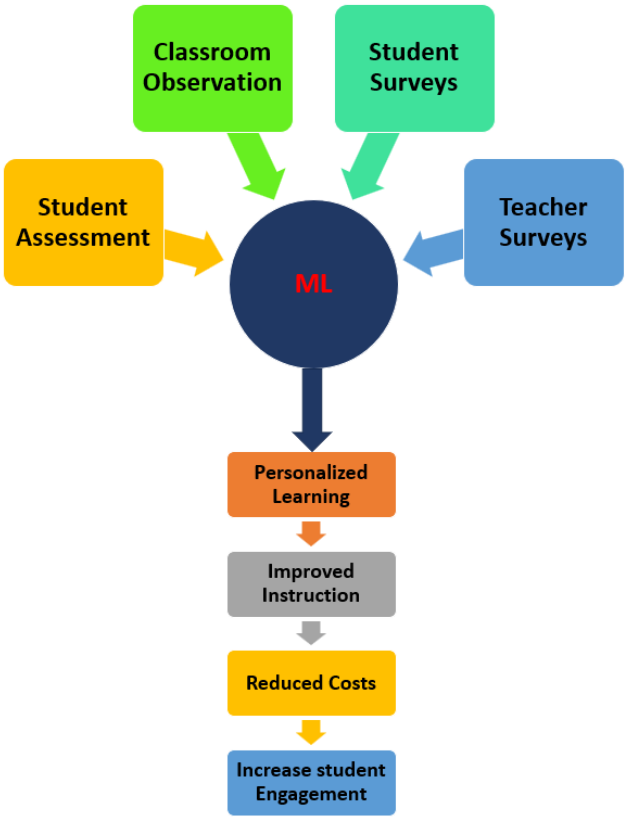

Figure 1: Architecture Diagram of ML based EdTech

3.1 Machine Learning Model

More and more, researchers in the field of education are using DM methods to learn more about how their kids do in school and what habits they have. There are different DM methods that can be used to look at a lot of educational data and help kids do better. These strategies help teachers find out which students need extra assistance or academic counselling. To put it another way, the metric used to calculate predicted is known as "regression." Regression shows the link between one or more variables that are independent and variables that are dependent. In prediction, data is organized based on expected actions in the future.

Data mining (DM) involves six steps or stages in machine learning process. Understanding the organizational aspect is the initial step in Ed-Tech. This step is cantered on comprehending the project goals and organizational standpoint. The next stage involves Data Understanding, where the initial data is gathered, data quality issues are pinpointed, and intriguing subsets are identified to generate hypotheses for uncovering hidden insights. Step 3 involves Data Preparation. During this phase, all essential tasks are carried out to construct the final dataset, including data cleaning, data transformation, and data selection. Next is the Modelling step, where different modelling techniques are chosen and implemented. Modelling is succeeded by the Evaluation stage, which assesses the model's value and its alignment with the established organization goals. Deployment is the final step that outlines the necessary actions to implement the developed models.

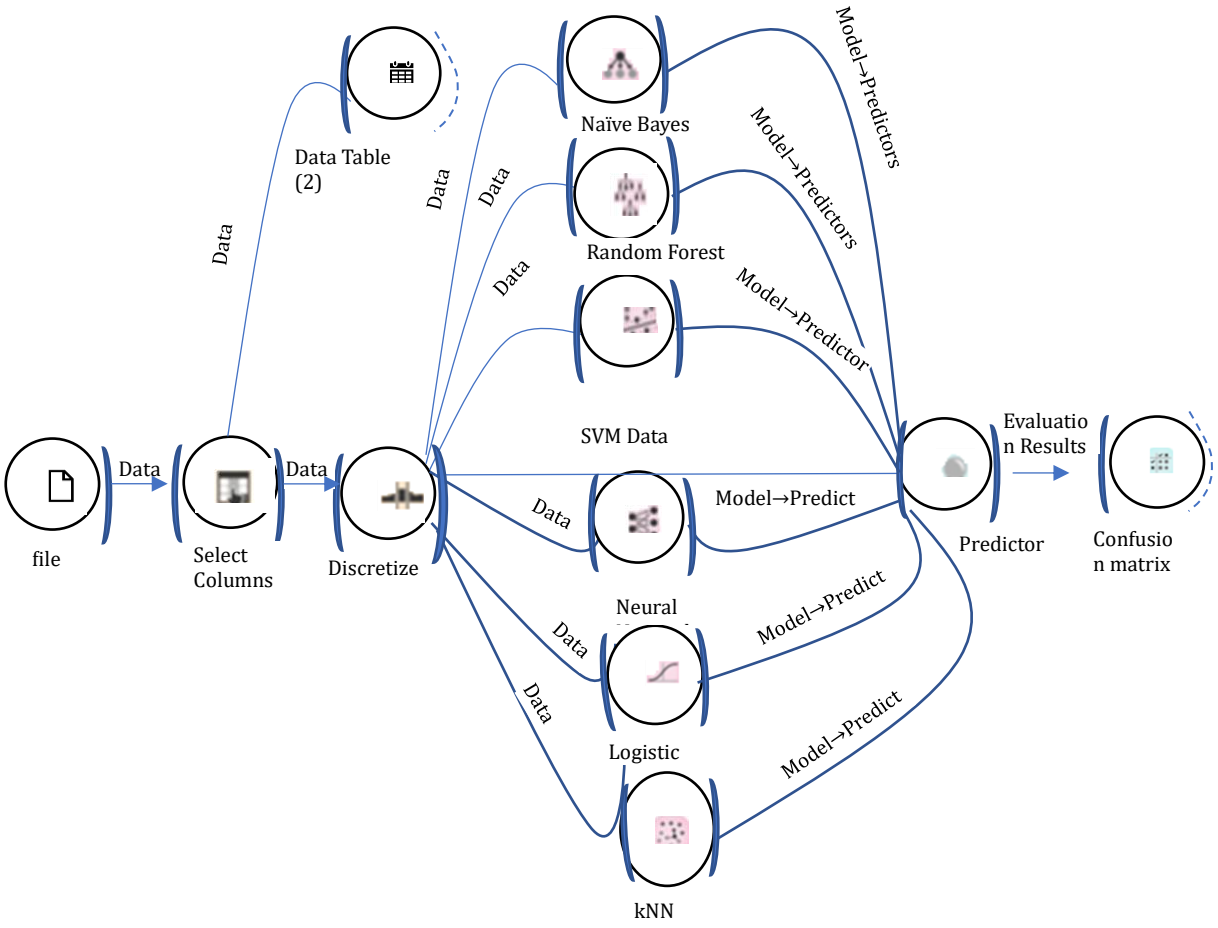

Figure 2: Performance Evaluation of Various ML Models

We utilized the DM model to implement algorithms such as NN, SVM, NB, RF, LR, KNN and NB for predicting students' academic performance. The analysis model of ML is given in Figure 2. The accuracy of the predictions was assessed through substantially validation across tests. The process of DM has two primary objectives. One of the main objectives is to predict outcomes by examining the data stored in the information system (predictive model). Another approach is to outline behaviours (descriptive model). When developing models for prediction, a model is generated by utilizing data with established outcomes. Subsequently, with this model, the predicted values are generated for datasets with unidentified outcomes. Descriptive models define patterns in existing data to facilitate decision-making.

3.2 Ed-Tech for Empowering Education

Based on the prediction of ML technologies, the EdTech offering the best way to change the conventional learning idea by the below mentioned learning skills.

- **Personalized Learning:** An important benefit of EdTech is its capability to customize studying experiences for students. Conventional classroom environments frequently face challenges in meeting the unique requirements of each student. Education technology tools and platforms have the capability to assess the learning preferences, areas of proficiency, and areas needing improvement for individual students. This allows teachers to customize their teaching approach and

content to better suit each student. Innovative learning algorithms enable students to advance at their own speed, guaranteeing a more profound comprehension of the topic.

- **Enhanced Education Access:** Educational technology can eliminate obstacles and broaden educational possibilities for individuals with restricted access. Due to educational platforms and Massive Open Online Courses (MOOCs), individuals from remote areas, communities that are marginalized, and those with physical disabilities have the opportunity to pursue education without being limited by geography. The promotion of inclusivity is having a positive effect on society by cultivating a more skilled and educated global population.
- **Improving Classroom Engagement:** Say goodbye to boring lectures and unengaged students. EdTech offers a variety of interactive tools such as digital modelling, virtual reality (VR), and augmented learning experiences to enhance education and make it more engaging and enjoyable. Through the use of immersive technologies, educators have the ability to foster curiosity and creativity in students, motivating them to look into complex ideas in an enjoyable manner.
- **Asynchronous Learning:** Asynchronous education involves lectures, projects, classes or seminars that do not occur simultaneously. With asynchronous courses or instruction, lessons are recorded in advance, allowing students to access learning resources at their own pace. There are courses that are entirely self-paced, while self-paced classes can also complement real-time discussions and activities in a remote or hybrid educational setup. In an asynchronous learning environment, the educational technology may consist of management systems for learning.
  - Self-Paced Modules
  - Online Practice Quizzes
  - Pre-Recorded Classes
  - Webinars, Lectures, And Conferences Are Available
  - Utilizing Online Conversations and Debate Boards
- **Synchronous Learning:** Classes involve all students and teachers being online simultaneously in synchronous learning. These online classes have set start times and are designed to replicate a traditional in-person classroom setting, unlike other self-paced courses. Students engage in classes and discussions live, allowing for immediate interaction. Education technology supporting synchronous learning may consist of video conferencing for various group sizes, real-time webinars, virtual classrooms, instant messaging, and live Q&A with student polling.

4 Result and Discussion

In this section, we have evaluated the performance of different machine learning techniques to determine the most effective educational technology methods.

4.1 Evaluation of the Model Performance

Evaluation of the model's performance was based on the following metrics:

- **Classification Accuracy:** Accuracy in classification is calculated by dividing the number of correct predictions by the total number of instances, given in Equation (1).

$$Accuracy = \frac{TN + TP}{FN + TN + TP + FP} \quad (1)$$

- **Precision:** When it comes to precision, it refers to the proportion of positive instances that are accurately classified out of the total instances predicted as positive. Retrieves a value within the range of [0.1]. The Equation (2) is illustrating the Precision value.

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

- **Recall:** Recall measures the proportion of positive instances that were correctly classified out of all actual positive events. The Recall is also known as the true positive rate, shown in Equation (3). Obtains a value within the range of [0.1].

$$Recall = \frac{TP}{TP + FN} \quad (3)$$

- **F1 Measures:** Precision and recall have an inverse relationship. Thus, the balanced average combining the two criteria is computed to achieve more precise and responsive outcomes. It is referred to as the F-criterion.
- **ROC Curve:** Assessing the effectiveness of a classification problem is commonly done using the AUC-ROC curve. The AUC-ROC metric is commonly utilized to assess the effectiveness of machine learning algorithms, particularly in scenarios involving imbalanced datasets, and indicates the model's predictive accuracy.

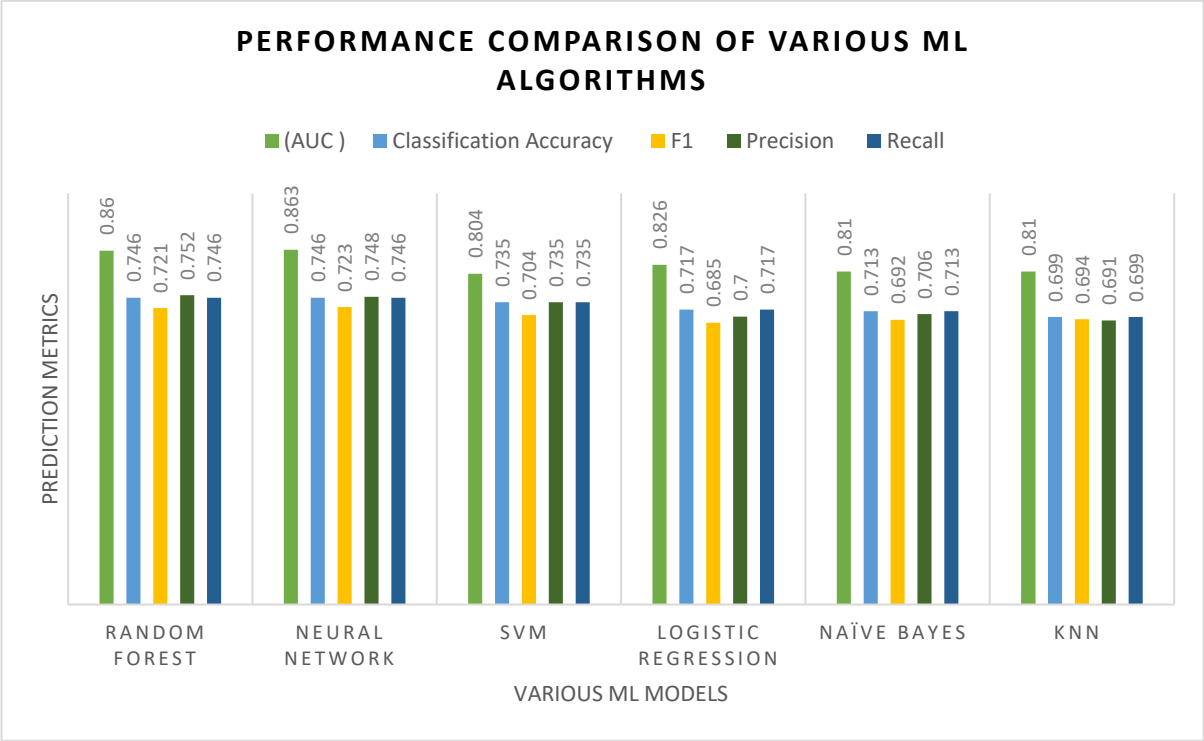

Figure 3: Performance Comparison of Various ML Algorithms

Figure 3 describes, the AUC values for the SVM, NB, RF, kNN, NN and NB algorithms were 0.804, 0.810, 0.860, 0.81, 0.863 and 0.810, in that order. The RF, NN, SVM, LR, NB, and kNN algorithms achieved classification accuracies of 0.735, 0.713, 0.746,0.699, 0.746 and 0.713, in that order. Based on these results, the RF algorithm achieved an accuracy of 74.6%. In short, there was a strong correlation

between the predicted data and the actual data. 74.6% of the items tested were classified correctly as a result.

5 Conclusion

The field of educational technology has transformed traditional education models, creating a more beneficial and customized educational environment. Education technology has the capacity to elevate the quality of education, enhance learning results, and empower both learners and educators across all levels of education, from kindergartens to colleges. Exploring the limitless possibilities of technology and embracing EdTech responsibly can lead us to a more improved based on knowledge future.

The frequent integration of machine learning in education has transformed this scenario, completely replacing humans in various aspects of the learning process. They can not only improve data processing but also significantly enhance the e-learning sector. Content has become increasingly relevant, with students now relying on digital assistants for guidance regardless of location or time. These technologies are the most important instruments for revolutionizing the whole e-learning sector and advancing the field's future because of their potential and capabilities.

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