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Evaluation of Students' Performance in Mathematics using Machine Learning Algorithms in Federal College of Education (Special), Oyo, Nigeria

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Abstract
This paper focuses on evaluation of students' performance in Mathematics using Machine Learning Algorithms in Federal College of Education (Special), Oyo, Nigeria. The study specific objectives are to: determine how machine learning algorithms enhance the evaluation of students' performance in Mathematics, determine how classifier metrics enhance the evaluation of students' performance in Mathematics. Two research hypotheses guided the study. Waikato Environment for Knowledge Analysis (WEKA) tool was used to evaluate students' performance in Mathematics which contains various machine learning algorithms. The population for the study comprised 6,982 students from 100 level, 200 level, and 300 level respectively. The sample size for the study consists of 3,642 students across the level. The instrument used for data collection was a Google form questionnaire, The following algorithms J48, Logistic Model Tree, Random Forest, Random Tree, RepTree, and Hoeffding Tree algorithms were used to evaluate students' performance in Mathematic and the following evaluation metrics were considered: Recall, Precision, F-measure, True-positive rate and False-positive rate. The results of the classification model indicated that the Random tree algorithm provides a better classification accuracy of 99.014%. The conclusion was arrived that the Random tree algorithm is the most suitable algorithm for performance evaluation because it yielded the best result in terms of accuracy, precision, recall, True False, False True, F-measure and other evaluation metrics. It was recommended among others that teachers should be adequately equipped by organizing workshops which will enable them to create an enabling environment for learners to be able to learn Mathematics effectively.

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Introduction

One cannot overstate the importance of evaluating students' performance, particularly in mathematics. Several elements such as emotion, peer influence, and environmental factors, may contribute to students' level of achievement or lack of interest in Mathematics. Therefore, students' performance in mathematics could be improved if this is identified and attended to either by the researcher or the teachers taking the subject. Waheed et al. (2020) submitted that early the is a novel phenomenon that involves ways of assessment to help students by suggesting suitable remedial strategies and policies in this area. Many approaches have been put in place to increase the student's performance in Mathematics. One of these is the application of Information and Communication Technology devices in teaching Mathematics and any other science-related courses (Leonard, 2018).

The utilization of machine learning algorithms has proven to be an effective means of predicting students" performance not only in Mathematics but also in various subjects; also prediction of both good and poor performance at different educational

levels has proven to be facilitated by the use of machine learning algorithms (Ofori et al., 2020). Using machine learning algorithms to evaluate or predict academic activities offers a more accurate way to predict academic performance; the education sector is presently utilizing machine learning techniques to predict future occurrences. The application of artificial intelligence-based machine learning algorithms has substantially filled in many of the gaps in conventional evaluation methodologies. Therefore, to predict students' performance, there would be a need to first of all acquire datasets, and subject the datasets to preprocessing to extract meaningful patterns or data from the datasets.

Machine learning called Waikato Environment for Knowledge Analysis (WEKA) was used in this paper to predict students' performance in mathematics. Mathematics is the study of figures, forms, and patterns that incorporate computation and reasoning science Mathematics could also be referred to as a systematic means of using symbols to describe ideas and relationships drawn from the environment (Kitta, 2004). Machine learning is a set of techniques that gives computers the ability to learn without any intervention of human programming data (Harikumar et al., 2012).

In addition to learning outcomes, which are the manifestation of students' potential or capacity, student performance in the educational process can be described literally as anything that results from behavioral changes based on experiences (Sudjana, 2010). To increase students' interest and performance in mathematics, it is crucial to both predict students' performance as early as possible and encourage learners' at all educational levels to develop an interest in the subject. Poor performance in mathematics is often the result of students' lack of interest in the core subject, mathematics. Since mathematics is essential to everything be it social reality, economics, or history it is widely believed that it makes understanding a variety of phenomena easier. For these reasons, mathematics serves as a useful tool for learning about all facets of human behaviour. Vamshidharreddy et al. (2020) predicted students' performance using decision trees, support vector machines (SVM), and Naïve Bayes algorithms and obtained the following results, the Naïve Bayes algorithm produced the best prediction model accuracy of 77.0%, followed by SVM with 38. 0% accuracy and a decision tree with 71.0% accuracy.

Dhilipan et al. (2021) predicted student performance by using a variety of algorithms, which include binomial logical regression, decision trees, entropy, and K-NN. The generated results showed that the decision tree model had an accuracy of 88.23%, while the accuracy of binomial logical regression was 97.05%, entropy was 91.19%, and K-NN was 93.71%. A machine learning-based model was proposed by Rebai et al. (2020) to identify the major factors influencing school academic performance and to ascertain the relationships among these factors. Regression trees, he concluded, demonstrated that the most significant variables linked to improved performance were gender proportions, class size, competition, school size, and parental pressure.

Data Mining Algorithms

Data mining algorithms are subsets of machine learning algorithms that are specifically designed to analyze, predict student performance, and create data models to find patterns of interest. The following algorithms were used in the performance evaluation of mathematics students using machine learning algorithms: J48, Logistic Model Tree, Random Forest, Random Tree, Rep Tree, and Hoeffding Tree algorithms.

J48 is a prediction tree machine learning model, one of the supervised learning algorithms in machine learning, which may be used to ascertain the precise value of a new sample based on different attribute values of the available data. The decision tree's internal nodes categorize the various algorithmic features.

Logistic Model Tree (LMT) is another supervised learning approach that combines the logistic regression and decision tree algorithms with two distinct classification algorithms. To produce a linear regression model, logistic model trees combine the use of decision trees with linear regression models on the leaves.

Random Forest Algorithm is a classification technique that utilizes several decision trees to increase the randomness of the model as the forest grows. Random Tree uses both classification and regression problems, this approach gathers predictor trees, also known as forests. A random trees classifier uses a feature vector as input and classifies it with each tree in the forest. It then produces an output representing the class whose label earned the most votes.

Reptree is a quick decision tree learner that can create regression or classification trees. It is based on the C4.5 algorithms.

The Hoeffding Tree is a form of decision tree that uses an algorithm for decision tree analysis that can be updated at any moment and learn from a vast number of datasets. The fact that a small sample size is frequently sufficient to choose the best-split attribute is exploited by this technique.

Objectives of the Study

This study aimed to evaluate students' performance in Mathematics using the following machine learning algorithms: J48, Logistic Model Tree, Random Forest, Random Tree, RepTree, and Hoeffding Tree algorithms. Specifically, the study sought to:

1. Determine how machine learning algorithms enhance the evaluation of students' performance in Mathematics
2. Determine how classifier metrics enhance the evaluation of students' performance in Mathematics

Hypothesis

Hypothesis H_{o1}: There will be no significant influence of analysis of algorithms on students" performance in mathematics

Hypothesis H_{o2}: There will be no significant influence of the Analysis of classifier metrics on students' performance in mathematics

Methodology

This section presents the stages of applying the data mining method for performance evaluation of students in Mathematics. The population for the study consists of 6,982 students from

the 100 level, 200 level and 300 level respectively from Federal College of Education (Special), Oyo, Nigeria. The sample size comprised 3642 student records which were subjected to preprocessing for data cleaning. Preprocessing of data involves data cleaning, session identification, and data conversion, the following algorithms: J48, Logistic Model Tree, RandomForest, RandomTree, RepTree and Hoeffding Tree algorithms were subjected to training using the collected dataset and models were generated. The generated models from this training were used in the test data. The training parameter was set to 10-fold cross-validation. The results of each algorithm were analyzed and compared in terms of accuracy, Recall, Precision, F-measure, True-positive rate and False-positive rate.

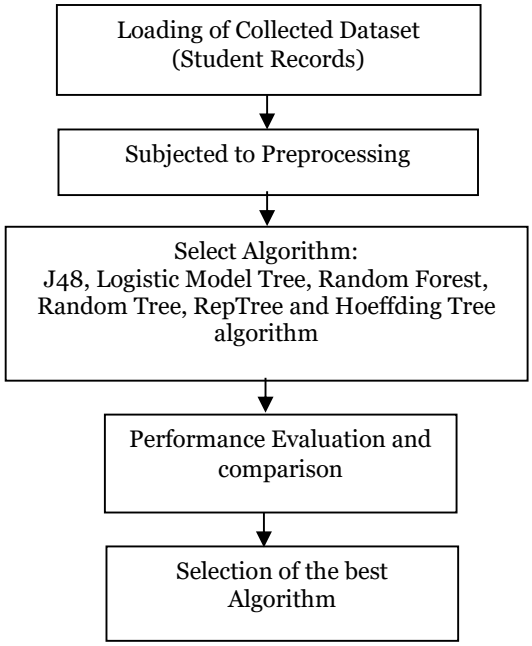

Figure 1: Block diagram of performance evaluation using selected algorithms

Table 1: Summary of Student Attributes Used

S/N	Attribute	Variable	Values
1	Age	Numeric	18-35
2	Gender	Binary	Male, Female
3	Matriculation Number	Numeric	1751081-2135032
4	Level	Numeric	300, 200, 100
5	Study time	Nominal	Morning, noon, night
6	Student Health Status	Nominal	Good, bad, worst
7	Attendance to lectures	Nominal	Good, bad, worst
8	Student Accommodation	Nominal	Within the school, outside the school
9	Early revision	Nominal	Before the exam, during the exam, after the exam
10	Academic achievement of parents	Numeric	1-2-3-4
11	Social economic status of parents	Nominal	Good, bad, worst
12	Parents job	Nominal	Self-employ, government
13	Class	Nominal	E-G-P-F

The attribute class is categorized into four namely: Excellent (E), Good (G), Pass (P) and Fail (F) which was used to determine the students' performance and this is depicted in Figure 2

Figure 2: Students' Performance Levels

Result

Hypothesis 1: There will be no significant influence of analysis of algorithms on students" performance in mathematics

Table 2: Showing the summary of analysis of algorithms on students' performance in Mathematics

Decision tree	Accuracy	Time taken to Build the Model
J48	85.1453%	0.02 seconds
LMT	80.4221%	0.05 seconds
Random Forest	89.3321%	0.02 seconds
Random Tree	99.0142%	0.02 seconds
RepTree	85.1453%	1.36 seconds
Hoeffding Tree	85.1453%	0.02 seconds

Table 2 depicts the experimental results obtained from the various classification algorithms in determining the best classification algorithms in terms of accuracy and time taken to build the model. From Table 2, it is observed that J48, Rep tree, and Hoeffding Tree classification algorithms give the same accuracy of 85.1453% with the same 0.02 seconds taken to build the model. The logistic Model Tree algorithm gives the lowest accuracy of 80.4221%, with 0.05 seconds to build the model. Also, the Random Forest algorithm gives an accuracy of 89.3321% with 0.02 seconds to build the model, while the Random Tree algorithm gives the best accuracy in terms of students' performance evaluation in Mathematics because the result yielded was 99.0142% Therefore, the random tree algorithm is the most suitable algorithm for determining students' performance in Mathematics.

Hypothesis 2: There will be no significant influence of analysis of classifier metrics on students' performance in mathematics.

Table 3: Showing the summary of analysis of classifier metrics on students' performance in mathematics.

Decision tree	TP Rate	FP Rate	Precision	Recall	F-Measure	Kappa Statistic	Mean absolute Error	Class
J48	0.645	0.534	0.786	0.598	0.692	0.6613	0.0125	Excellent
	0.005	0.034	0.006	0.008	0.002	0.0013	0.0015	Fail
	0.345	0.334	0.286	0.598	0.192	0.3613	0.0125	Good
	0.245	0.234	0.186	0.498	0.180	0.3513	0.0120	Pass
LMT	0.643	0.524	0.766	0.588	0.682	0.6513	0.0120	Excellent
	0.045	0.034	0.086	0.098	0.102	0.0013	0.0125	Fail
	0.244	0.232	0.690	0.698	0.794	0.5650	0.0091	Good
	0.240	0.232	0.184	0.398	0.170	0.2513	0.0121	Pass
Random Forest	0.745	0.534	0.786	0.598	0.692	0.6613	0.0125	Excellent
	0.045	0.034	0.086	0.098	0.092	0.0613	0.0015	Fail
	0.245	0.234	0.691	0.697	0.796	0.5640	0.0092	Good
	0.24	0.234	0.186	0.498	0.180	0.3513	0.0120	Pass
Random Tree	0.997	1.000	0.999	0.984	0.892	0.7508	0.1117	Excellent
	0.045	0.034	0.086	0.058	0.092	0.0613	0.0015	Fail
	0.645	0.534	0.786	0.598	0.692	0.6613	0.0125	Good
	0.245	0.234	0.286	0.298	0.392	0.2613	0.0025	Pass
RepTree	0.645	0.534	0.786	0.598	0.692	0.6613	0.0125	Excellent
	0.035	0.033	0.076	0.096	0.082	0.0513	0.0019	Fail
	0.447	0.234	0.286	0.498	0.592	0.0613	0.0015	Good
	0.256	0.023	0.570	0.434	0.532	0.0112	0.0002	Pass
Hoeffding Tree	0.725	0.434	0.784	0.592	0.672	0.653	0.0125	Excellent
	0.022	0.122	0.025	0.023	0.021	0.2111	0.0012	Fail
	0.234	0.286	0.598	0.698	0.515	0.4112	0.0044	Good
	0.045	0.034	0.086	0.098	0.092	0.0613	0.0015	Pass

Table 3 also presents the true positive rate, false positive rate, precision, recall, f-measure, kappa statistic and mean absolute error of different classifier models. These metrics were used for performance evaluation. From this table, it was clearly stated that 0.997, 1.000, 0.999, 0.984, 0.892, 0.7508 and

0.1117 respectively have the highest true positive rate, lowest false positive rate, precision, recall, F-Measure, highest Kappa statistic and mean absolute error. Therefore, these results are all under excellent, implying that students perform excellently well in Mathematics. Also the above metrics confirmed that the chosen algorithm gives very satisfactory results.

Table 4: Confusion Matrix of different classifiers

Classifier	Excellent	Fail	Good	Pass	Class
J48	53	2	7	6	Excellent
	2	45	9	1	Fail
	6	2	50	4	Good
	3	5	10	44	Pass
LMT	53	4	5	4	Excellent
	4	60	7	0	Fail
	5	2	43	7	Good
	7	10	4	41	Pass
Random Forest	58	2	6	2	Excellent
	4	42	4	1	Fail
	10	2	32	2	Good
	2	1	6	20	Pass
Random Tree	66	1	3	2	Excellent
	3	87	2	0	Fail
	4	10	45	1	Good
	7	2	4	60	Pass
RepTree	53	3	2	2	Excellent
	5	43	1	0	Fail
	4	2	40	1	Good
	2	2	6	37	Pass
Hoeffding Tree	55	45	2	2	Excellent
	3	32	1	0	Fail
	2	6	34	2	Good
	2	8	3	41	Pass

Table 4 depicts the confusion matrix of different classifiers that were used. The confusion matrix summaries the overall performance of students as shown above.

Discussion

The result of this study revealed that machine learning algorithms are a sophisticated tool for evaluating students' performance in mathematics and other subjects, based on the result achieved it was revealed that Random Tree algorithm gives the best accuracy in terms of performance evaluation of students in Mathematics because it yielded 99.0142% therefore, Random Tree algorithm is the most suitable algorithm for determining students' performance in Mathematics this is in line with the submission of Pack et al., (2009) that stated that machine learning algorithms are the most and highly effective for performance evaluation and further submitted that Random Tree algorithm yielded the best result in prediction students' performance.

The finding also revealed that students performance in Mathematics was better than ever before because information and communication technology devices and mathematical software have been integrated into the teaching and learning of mathematics and based on the following results of true positive rate, false positive rate,

precision, recall, F-Measure, highest Kappa statistic and mean absolute error which is: 0.997, 1.000, 0.999, 0.984, 0.892, 0.7508 and 0.1117 are okay therefore random tree algorithm gives very satisfactory results this is in line with the submission of Powers (2011) which submitted that the application of True Positive rate, True Negative rate, Recall, Precision, mean absolute error and F-measure are argued to be best evaluation metrics in determining students' performance.

Conclusion

In conclusion, the performance evaluation of students in Mathematics is one of the prominent quality indicators for every institution of learning. In this research work six machine learning algorithms were examined to evaluate students' performance in Mathematics. The six machine learning algorithms that were used are J48, Logistic Model Tree, Random Forest, Random Tree, RepTree, and Hoeffding Tree algorithms. Based on the findings Random Tree algorithm gives very satisfactory results which imply that its suitability in evaluating students' performance was yielded in the result obtained which is 9.0142%.

Recommendations

The following recommendations were made, based on the findings of this study:

1. Teachers should be adequately equipped by organizing workshops that will enable them to create an enabling environment for learners to be able to learn Mathematics effectively.
2. Students' performance should be improved by integrating more ICT devices into teaching and learning mathematics in higher institutions of learning in Nigeria.
3. Learning outcomes of students should be improved by integrating Machine learning models.
4. Government should provide more ICT devices and mathematical software that will aid the teaching and learning of Mathematics in higher institutions of learning in Nigeria.

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