

Performance Based Prediction of the Students in the Physics Subject using Traditional and Machine Learning Approach at Higher Education Level

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Abstract

In higher educational institutions, it is not an easy task to judge the performance of the students timely which is becoming more challenging. Although institutions have gathered a lot of data about their students. They do not have some specific methods to extract meanings from it. The main objective of this study was to find out the performance-based prediction of the students using their demographic and academic factors by using traditional and machine learning approaches. Graduates and undergraduate students studying in KUST were the population of the study. The study was delimited to the department of physics. A total of ninety graduate and undergraduate students were selected randomly using a simple random sampling technique as the entire sample. The result indicated that percentage in matric (Correlation = 0.304), intermediate (Correlation = 0.245) and National Aptitude Test scores (Correlation = 0.480) found the best predictors. Further research was recommended to predict students' academic performance by taking other aspects of the students like personality, cognitive, psychological, and economic domain for making a dataset of the features which may be used in machine learning approach which is more reliable to judge the academic performance of the students at the higher education level.

Keywords: *Performance, Challenging, Demographic, Prediction, Examination*

1. Introduction

Educational institutions may be developed academically if we know the learning process going on into those institutions because of having its critical role

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in educational development. In this way, one can get several benefits in which one of the benefits is to improve students' outcomes and it helps the teachers to improve the students' outcomes. The teacher can assist the students who are weaker in their planning in academics. This attempt may become beneficial for the organization in decreasing the failure cases or dropping out of the courses (Badr, Algobail, Almutairi, & Almutery, 2016).

In research, Buniyamin, Arsad, and Kassim (2013) explained that generally, it has been investigated that at the tertiary level performance of the students is being measured with the help of using final grade or CGPA as an attribute. Other than the final grade, marks achieved in assignments, grades per course, total assessment marks, and co-curricular activities are being considered for measuring the performance of the students. The academic performance of the students has been considered as the most important task in the study institutions. Early and timely prediction helps to find out the weaknesses and strengths of the students in all respects. There are diverse aspects that may affect the performance of the students during their studies. Those factors may be social, demographic, and concerning to the academic. Academically, grades or marks in the previous classes are of great importance because these help to identify the abilities of the students and play a very significant role in predicting their final grades or performance (Roy & Garg, 2017).

The demographic variable in which gender has been used by different researchers because males and females have different learning ways during their learning process (bin Mat, Buniyamin, Arsad, & Kassim, 2013). In a research study, females were found more dutiful, focused, and disciplined and having different effective learning strategies while studying (Simsek & Balaban, 2010). Keeping because of these studies, it has proven that in measuring the academic performance of the students, gender has been taken as an important aspect that affects or plays its role in students' academic performance.

Adebayo (2008) has written in one of the research that among the predictors used in predicting the students' academic performance, some cognitive variables like class marks, standardized test scores, grades achieved in high schools and class rank were found good variables to predict students' performance especially about the students who become the regular students of the educational institutions.

At present, there are so many different techniques due to which one can measure the performance of the students in which the most common technique is the data mining technique. This technique is being widely used in different educational institutions throughout the world. The information that we extract

can be used for measuring the performance of the students before time (Shahiri & Husain, 2015).

Huang and Fang (2013) explained in their research study that the results which we take by using a predictive model may become very useful for those who are having less potential and may be helpful for such students in building better strategies before the final examination. The prediction may alarm them that how would they perform in the future and in this way they can move ahead with new thinking and hard work. Students may get new thinking to revisit their ways of learning for getting good results in the future.

In 2016, a research conducted by Mueen, Zafar, and Manzoor who explained that data mining technique is most suitable to find out the performance of the students academically and they also have suggested that further research may be conducted at different education level by including more variables which may be utilized to know about the performance of the students. In this way, we may be able to make the existing online system to analyze the performance of the students automatically.

In the current learning process, the parameters which have been taken after data pre-processing were CGPA as the dependent variable and independent variables i.e., Gender, Name of Domicile District, Marks in Matric and in intermediate, Type of the School & College, whether that was public, private or semi-public, NAT score and for measuring the performance of the students on academic base, a traditional method using SPSS v24, and Neural Network with linear regression has been used to measure the academic performance of the students. This research helps to find out the variables which may be used for measuring the prediction of the students or will be taken as good predictors to predict students' academic performance.

1.1 Objectives of the Study

Objectives of the study included:

1. To find out the variables used for measuring the academic performance of the students at the higher education level.
2. To predict the academic performance of the students at the undergraduate level.

1.2 Research Questions

The study comprised the following research questions:

1. What are the variables being considered as the best predictors?
2. What is the difference between traditional and machine learning approach to predict the performance of the students at the tertiary level?

1.3 Significance of the Study

The current study may be a base for developing a predictive model and may help to build a data set of the variables which may be used for prediction of the students before taking their final examination and also before enrolment of the students at the time of admission. This will also help to support the students who will be at a lower level concerning their academic performance. Performance of the students may find out before time which may be beneficial for the students due to which they may become more conscious before time. They may improve their abilities for final grades before appearing in the final examination. Different academic factors may be analyzed and recorded in this phenomenon for initiating the weaknesses well in time. Such study may help to bring new changes into the current online program of KCMS (KUST Campus Management System) and may become more strengthen for the students as well as for the teachers to know about the current situation of the students in a particular course by integrating best predictors into the e-portfolios of the students. This study also initiates to predict students' academic performance by using a machine learning tool that may bring new change into the evaluation system of any educational institution.

2. Literature Review

The main reason is to have a rational understanding of the best method for measuring the academic performance of the students at the tertiary level to fulfill the gaps in the current study with new research activity in the field of education (Shahiri & Husain, 2015). Review of related literature has its aim to provide support for making research questions and will help to reach the conclusion which is also most useful for identifying the scope of the study. It has been revealed through literature that different predictors have been taken to predict the academic performance of the students. Commonly used variables in predicting students' performance were CGPA & assessment marks during internal evaluation. In many research studies, a variable of CGPA was used as the main predictor to forecast students' academic enactment (Mayilvaganan & Kalpanadevi, 2014; Christian & Ayub, 2014; Rusk & Song, 2013; Jishan, Rashu, Haque, & Rahman, 2015). Due to having tangible value CGPA has been used for educational and career advancement which may be called or being indicated as the real academic potential (bin Mat & Buniyamin, 2013).

Different researches showed that students' demographic variables like gender, age, family background, and disability were being used in measuring students' performance in educational institutions (bin Mat, Buniyamin, Arsad, & Kassim, 2013; Naren, 2014). Literature explained that variables like school

background, human interaction, and different extra co-curricular activities have been used to measure students' academic performance (Naren, 2014). Adebayo (2008) argued about the variables used to predict student' performance were standardized test scores such as ACT (American College Testing). It was mentioned that some cognitive variables like standardized scores were the significant predictors to predict students' success.

Traditional methods of prediction are those in which traditional statistical methods are to be used like mean, median, Chi-Square, regression, and factor analysis as it was stated by the Ayan & Garcia in 2008, which have been applied in the prediction of the students' academic performance. Moreover, in 2007, research conducted by Vandamme, Meskens, & Superboy, then in 2008, research conducted by Imbrie, Lin, Reid, & Malyscheff and in 2009, research study conducted by Lykourantzou, Giannoukos, & Mardis who explained that some current methods have also been used to measure the academic performance of the students in educational institutions.

Modern methods of prediction are those in which there is a use of machine learning using an educational data mining approach which has been considered the most effective for measuring academic performance. In developing, predictive models for students' evaluation in educational setup different tasks are being used like classification, regression & categorization. Mathematical techniques like (DT) decision tree, (NB) Naïve Bayes, ANN, & (SVM) Support Vector Machine have been taken into the different researches to predict the performance of the students (Shahiri & Husain, 2015).

The most reliable technique which is frequently used by the different educational organizations to measure the academic performance of the students is an artificial neural network that has this ability to find out all possible relations and interactions between predictors variables (Gray, McGuinness, & Owende, 2014). This is also being used for detecting a complex relation between or among dependent and independent variables (Arsad & Buniyamin, 2013). Currently, variables taken were; semester's name, batch No, name, Parent name, Gender, Domicile District, Name of Village, Matric Marks, Total Matric Marks, Type of the School & College, Marks obtained in F.Sc with it total marks, NAT Score, and final CGPA of the semester.

In 2017, research was carried out by Gerritsen that highlighted the importance of Educational Data Mining recently. This is having a link with the data available nowadays through digital accessible tools and researchers, educational institutions, and the government is seeking to utilize this data in a better way to find some meaningful patterns from that available data. In this research study, 90 participants (students) studying at Kohat University of Science

& Technology were taken and information has been taken regarding their demographic and academic background. Emphasis was also done on using machine learning techniques with Artificial Neural Network in knowing the academic performance of the students.

3. Research Methodology

The current research study was conducted in KUST, Kohat, Khyber Pakhtunkhwa, Pakistan. The main objective of the study was to predict the academic performance of the students at the tertiary level. This study was conducted in pursuance of finding out the variables best associated with the academic performance of the students by using the traditional method of analysis i.e., SPSS v.24 and modern approach (ANN). Data were collected from the Department of Physics, KUST, Kohat including possible factors that were easy to collect from the students.

3.1 Research Design

The research design was survey-based and quantitative.

3.2 Population of Study

Graduate & undergraduate students (male & female) studying in the Kohat University of Science and Technology in semester Fall-2018 to Fall-2019 (total 6410) were taken as the population of the study. The study was delimited to the Department of Physics only.

3.3 Sample and Sampling Technique

Ninety students in total, studying at graduate & undergraduate level in the Department of Physics were taken as a sample of the study. The sample of the study was selected randomly using a simple random sampling technique.

3.4 Instrumentation

A questionnaire was used to collect the information based on the research-based variables as considering predictors to predict the performance of the students. Those were semester name, batch No of the students, personal name of the students, Parent name, Gender, Domicile District, Name of Village, Matric Marks, Total Matric Marks, Type of the School & College, Marks obtained in F.Sc with it total marks, NAT Score, and final CGPA of the first two semesters.

3.5 Data Collection

Data were collected and a data set was prepared to find out their association with the dependent variable (CGPA). Then variables were critically analyzed and used to measure the prediction of the students' performance. Prediction about the performance of the students was checked through both

traditional (using SPSS v.24) and machine learning (ANN) approach and then compared the performance of the students. In which the machine learning approach was chosen as the method to predict the performance of the students.

4. Data Analysis and Interpretation

The prepared dataset was analyzed by using statistical tools including correlation and multiple regression through SPSS v24. After finding the correlation of each independent variable with the output variable which was CGPA was checked. Detail of the data analysis was as follows:

Table 4.1

Previous Achievements of Students at Department of Physics, KUST

S.No	Domicile District	Percentage in Matric	Percentage in Intermediate	NAT Score	CGPA in First Semester
1.	Kohat	72.12	66.69	48.29	2.39
2.	Karak	74.18	73.89	52.13	2.49
3.	Dir Lower	74.18	73.89	52.13	2.49
4.	Khyber Agency	75.52	73.64	52.00	2.62
5.	Lakki Marwat	77.91	70.50	49.17	2.82
6.	Hangu	67.83	62.82	45.25	2.69
7.	FR Kohat	74.95	70.00	45.00	2.44
8.	Orakzai Agency	71.96	69.02	47.85	2.35
9.	FR Bannu	76.07	71.13	58.00	2.91
10.	Charsada	74.64	74.36	46.00	3.12
11.	Peshawar	76.01	69.47	56.00	3.27
12.	Malakand	76.00	71.09	51.00	3.54
13.	South Waziristan	73.50	68.28	44.00	1.46
14.	Bajur	80.55	73.45	66.00	3.66
15.	North Waziristan	72.37	67.05	45.00	2.19
16.	Others	73.56	67.28	51.30	2.91

Data were segregated area wise first to see the performance of the students that they have achieved in the past. The basic purpose was to see the analysis of the students in-depth that in which location of the Khyber Pakhtunkhwa, there is a need to pay our attention to having good students at the higher education level. The table 4.1 shows that students studied in district Bajur have high marks in matric (Mean = 80.56). Then in the district, Lakki Marwat students achieved good marks (Mean = 77.91). The highest marks gained by the students at an intermediate level were in district Bajur (Mean = 66.00) and then in the district, FR Bannu (Mean = 58.00) was high. Detail of students' academic

performance at matric level and an intermediate level is visualized through the following graph.

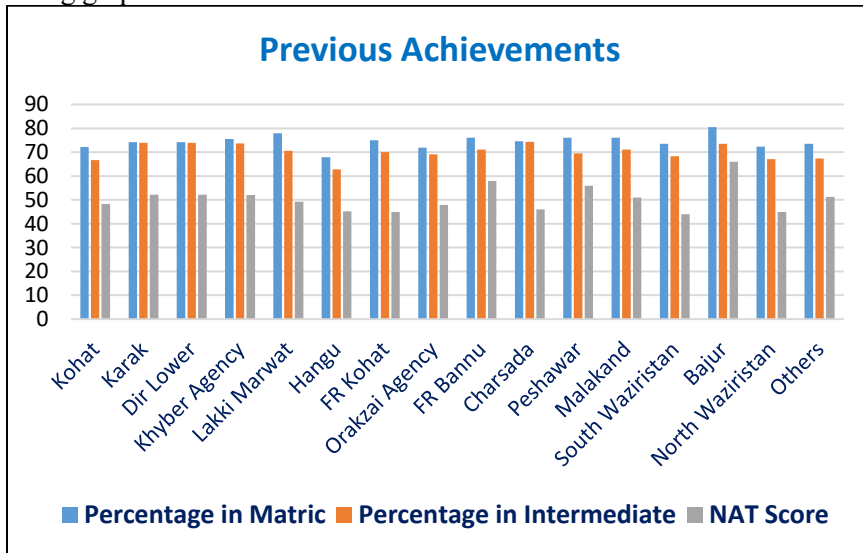


Figure 1. Previous Achievement of the Students studying in the Department of Physics, KUST

Data analysis showed that the performance of the students at the matric level in a government school (Mean=74.33) was better than private schools (Mean=73.09). Similarly, at the college level, the performance of the students (Mean=68.42) was better than private institutions (Mean=68.21). The detail is given in the following table.

Table 4.2

Performance of Educational Institutions in Khyber Pakhtunkhwa

S.No	Level of Institute	Status	Matric (Mean)
1.	School	Government	74.33
2.		Private	73.09
3.	College	Government	68.42
4.		Private	68.21

Result in table 4.2 showed that in Khyber Pakhtunkhwa, overall performance in government schools (Mean = 74.33) were better than private institutions (Mean= 73.09) and at intermediate level government colleges (Mean = 68.42) was better than private institutions (Mean = 68.21).

Table 4.3

Prediction of the Students' Academic Performance through ANOVA

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20.881	7	2.983	6.39	.000 ^b
	Residual	38.234	82	.466	8	
	Total	59.116	89			

a. Dependent Variable: CGPA in First Semester

b. Predictors: (Constant) , College Status , Domicile District , Percentage in Intermediate , Gender of the Students , NAT Score , Percentage in Matric , School Status

Table 4.3 shows that model is significant in which independent variables were College Status, Domicile District, Percentage in Intermediate, Gender of the Students, NAT Score, Percentage in Matric, School Status and the dependent variable was CGPA obtained by the students studying in Department of Physics, KUST, Kohat. Model prepared by using a linear regression model was significant (0.000) having a positive correlation (0.594) of independent attributes with the dependent predictor. 'R' sqr value (0.353) value shows that 35% variance exists. Durbin Watson's value (1.974) shows that predicted value has a positive correlation with the residual.

Table 4.4

Summary of Students' Prediction

Mode	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.594 ^a	.353	.298	.68284	1.974

a. Predictors: (Constant), College Status , Domicile District , Percentage in Intermediate , Gender of the Students , NAT Score , Percentage in Matric , School Status

b. Dependent Variable: CGPA in First Semester

The undermentioned graph shows the normality of the data which indicates that independent variables having a good impact on the dependent variable.

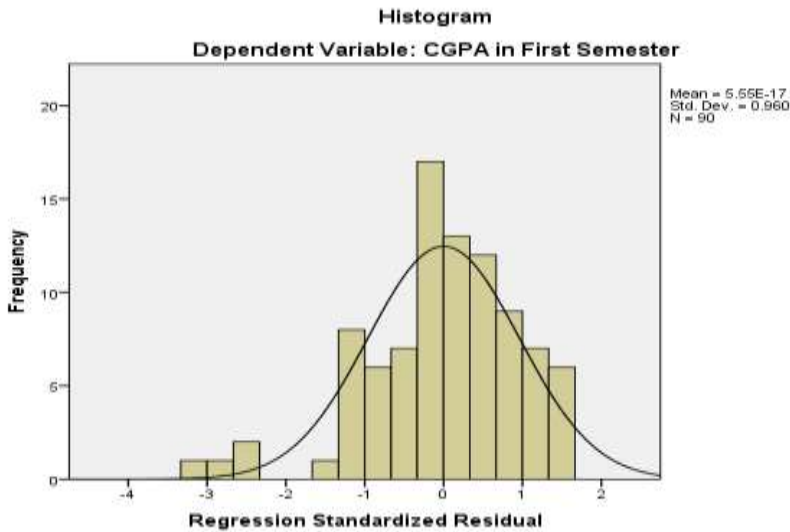


Figure 2. Data Distribution Graph

The following table explains the relationship of each independent aspect (predictor) with the dependent variable (CGPA).

Table 4.5

Significance of Independent Variables with Dependent Variable (CGPA)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-	1.016		-	.056		
		1.972			1.940			
	Gender of the Students	.329	.295	.101	1.117	.267	.960	1.042
	Domicile District	.025	.013	.171	1.862	.066	.931	1.075
	Percentage in Matric	.006	.013	.054	.514	.609	.710	1.408
	School Status	.132	.299	.077	.441	.661	.261	3.836
	Percentage in Intermediate	.025	.012	.215	2.077	.041	.734	1.362
	NAT Score	.048	.013	.356	3.750	.000	.873	1.145
	College Status	-.419	.295	-.248	-	.159	.260	3.847
					1.422			

a. Dependent Variable: CGPA of First Semester

Table 4.5 shows that all independent predictors have some positive connection with the dependent attribute in which the most suitable predictors were percentage in intermediate having significance value (0.041) which is less than the alpha value of 0.05 level and another predictor was NAT score having significance value (0.000) at 0.05 alpha level value. Collinearity statistics showed that every independent aspect is quite having positive control over dependent predictor while all VIF values are also showing the positive impact of each self-governing variable. The following graph shows the prediction of the students' academic performance.

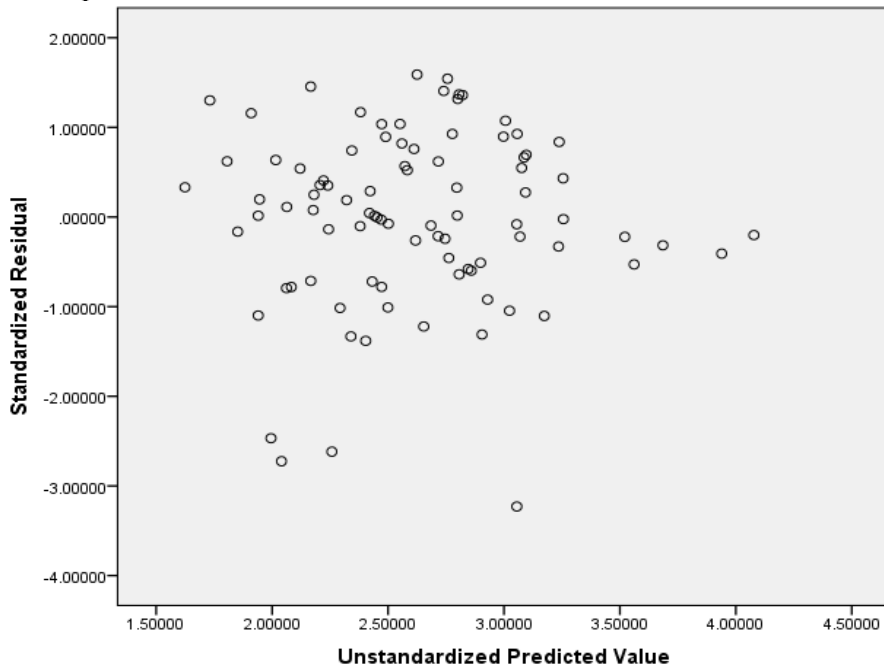


Figure 3. Relationship between Standardized Residual and Unstandardized Predicted Value

In 2016, a research conducted by Martinez Abad & Chaparro Caso Lopez who explained that estimation can be made by using a regression model with Neural Network because of having input and output dataset. Each data input contains some weight with it and due to neural Network which has this advantage to extract some meanings from the complex data which seems a most difficult task for both human beings and computers as well. Using data of the participants studying in the Department of Physics, KUST was then analyzed through ANN

(Artificial Neural Network) using a linear regression model, and the performance of the students was predicted. In this model, 30% of data were used for exercise drive and the remaining data were used for predicting students' academic performance. The result is given below:

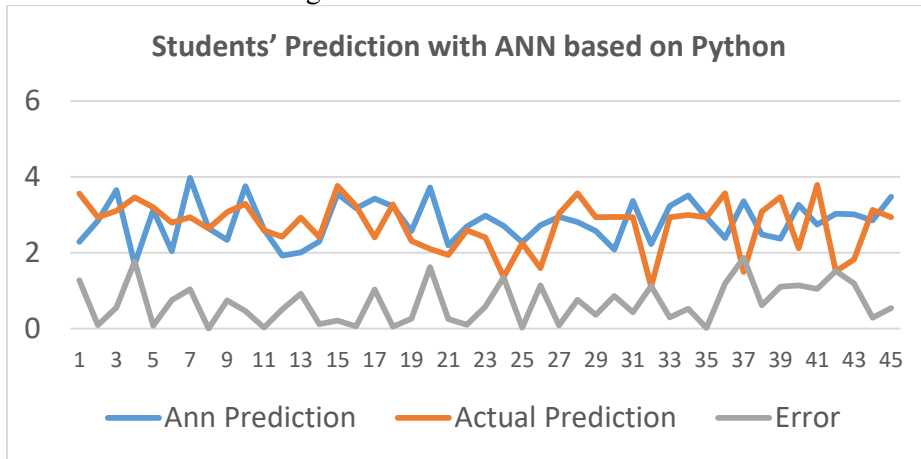


Figure 4. Prediction of the Students' Academic Performance with ANN

Table 4.6

Correlation of Independent Variables with Dependent Variable (CGPA)

	Gender	Domicile District	Matric %	School Status	F.Sc %	NAT Score	College Status
Gender	1.0						
Domicile District	-0.17	1.0					
Matric %	0.141	0.086	1.0				
School Status	0.094	-0.102	-0.086	1.0			
F.Sc %	0.024	0.028	0.489**	-0.013	1.0		
NAT Score	0.037	0.171	0.263*	-0.130	0.262*	1.0	
College Status	0.105	-0.001	-0.114	0.853**	-0.014	-0.122	1.0
CGPA	0.106	0.234*	0.304**	-0.196	0.245**	0.480**	-0.224*

Result of table No 4.6 showed that correlation of the each independent variables like Gender (correlation = 0.106), Name of Domicile District (correlation = 0.234), Marks in Matric (correlation = 0.304) and in intermediate (correlation = 0.245), Type of the School (correlation = -0.196) & College (correlation = -0.224), whether that was public, private or semi-public, NAT score (correlation = 0.480) was found with the dependent variable i.e., students' output (final CGPA). These variables were finalized during data preprocessing using multiple regression. By using ANN, the prediction was checked which was very significant to predict the academic performance of the students achieved in

the next semester. Keeping because of the performance of the students and variables taken for doing prediction of the students' academic performance percentage in intermediate (significant at $p\text{-value} = 0.041$) and NAT scores (significant at $p\text{-value} = 0.000$) were found good predictors to measure students' academic performance. Although other variables were having less correlation with the outcome (CGPA) of the students. Overall in government institutions were better than private institutions which indicates that a little attention may give us better results in education.

5. Discussion

In this section, researchers discussed how the main objectives were achieved and how much it is useful for developing a predictive model to measure the academic performance of the students. The main factors were demographic and some cognitive variables which have been purely connected to the previous achievement of the students in their academic career. Multiple linear regression method was used to know the academic performance of the students. Different variables that have been used in finding out the prediction of the students' academic performance were CGPA, assessment marks (Mayilvaganan & Kalpanadevi, 2014; Christian & Ayub, 2014; Rusk & Song, 2013; Jishan, Rashu, Haque, & Rahman, 2015). Mayilvaganan and Kalpanadevi (2014) explained the association of each variable with the academic performance of the students and used different advanced techniques like Naïve Bayes, and K-Nearest Neighbor. Using different techniques may affect the results of the studies if researchers use a different set of variables. The study investigated the low performers and helped to identify the failure in the educational institutions and then suggested using the manual method like feedback etc for identifying the overall performance of the students. Demographic variables like age, gender, family background (bin Mat, Buniyamin, Arsad, & Kassim, 2013; Naren, 2014). Researches explained that the predictive model can predict before time to highlight the weaknesses of the students just after enrolment at higher education institutions. It was suggested to use such methods in other countries also by using different data sets. Naren (2014) explained that a suitable way to get success in life may be guided to the students and students always must be disciplined to get success in the future. Problems of the students may be predicted before time with the help of a predictive model based on different educational and demographic backgrounds. Modern techniques like Naïve Bayes and Neural Network suggested predicting the performance of the students using different variables associated with the academic performance of the students. Entrance test marks also were taken into consideration to predict students' academic performance (Adebayo, 2008).

6. Conclusions

The following conclusions were made:

1. It has been concluded that predictors play an important role in measuring the academic performance of the students.
2. The result showed that if few cognitive variables have such a good effect on the academic performance of the students then other domain may also have their role in measuring the academic performance of the students like personality, economic, psychological, and more academic factors.
3. Among the variables used in this study percentage in intermediate (Correlation = 0.304) and NAT scores (Correlation = 0.245) were found the best predictors.
4. It has been proved that ANN was the best tool that may be taken to predict the academic performance of the students instead of using traditional statistical methods.
5. This study helped encourage to find the best predictors for the future development of the comprehensive predictive model that may be used to know students' academic performance well in time.
6. In the context of the educational culture in any educational institution, a data set may be prepared which may be used for ML (machine learning) to predict students' academic performance.

7. Recommendations

1. It is recommended that economic factor is also has a vital role in the students' academic performance which could not be included due to pilot study. Researchers may include different economic factors like parents' job status, monthly income of the family, etc to predict the students' academic performance. Researchers may include more academic factors, personality factors, and psychological factors.
2. It has been recommended to prepare a data set including all possible features that affect the academic performance of the students which may be used in machine learning for their future prediction in education. Moreover, different algorithms used by the ML (machine learning) like support vector machine, decision tree, naïve Bayes algorithm may also be used to compare the accuracy of the algorithms which may be used to predict students' academic performance.

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