Journal of Engineering and Technology
DergiPark
AKADEMİK

Journal of Engineering and Technology 3;1 (2019) 1-11

Predicting Factors Affecting PISA 2015 Mathematics Literacy via Radial Basis Function Artificial Neural Network

[a]*Özlem BEZEK GÜRE, [b]Murat KAYRİ, [c]Fevzi ERDOĞAN

[a]*Medical Documentation and Secretarial Batman University,Batman, Turkey, ozlem.bezekgure@batman.edu.tr

[b]Computer Engineering Batman University Batman, Turkey, murat.kayri@batman.edu.tr

[c]Econometrics Department Yüzüncü Yıl University Van, Turkey, ferdogan@yyu.edu.tr

ARTICLE INFO

Article history:
Received 12 Feb 2019
Received in revised form 7 March 2019

Accepted 8 March 2019
Available online 23 May 2019

Key words:
PISA,
Data Mining,
Radial Basis
Artificial Neural Network

* Corresponding author.
E-mail address:
ozlem.bezekgure@batman.edu.tr

ABSTRACT

In this study, radial basis function artificial neural network (RBFN), which is one of the of data mining methods, was employed to determine the factors affecting PISA 2015 (Programme for International Student Assessment - PISA), Mathematics literacy. Mathematics literacy scores, which were made in categorical form with three level dependent variables, 25 independent variables, and considered to have affected the dependent variables, were employed in evaluating and validating the proposed method. Also, in order to determine factors affecting PISA 2015 Mathematics literacy, information obtained from a total of 4422 students (2165 (49%) of whom were males and 2257 (51%) of whom were females) who participated the exam was used. According to the obtained results, the correct classification rate of mathematics achievement in the radial based artificial neural network model was found to be 85.2%. In addition, it is seen that the most important factor that were affecting Mathematics literacy was Turkish language success status and the other variables that were setting significance are targeted point in school life, father education level and mother education level.

1. Introduction

PISA is a large scale educational survey that was financed by Organization for Economic Cooperation and Development (OECD). In PISA exams; Science, Mathematics literacy and reading skills of students at the age of 15 are evaluated. Additionally, it collects information about the student, learning styles of the student, the school and family environment of the student. PISA was held in 2000 for the first time, and our country, Turkey, has been participating in this exam since 2003. The member countries of OECD and other participating countries take place in this exam, which is held once in three years periodically. In each session of exam, one of the skills of science, mathematics and reading is focused on [1, 2, 3, 4]. Initially, PISA exams are performed as paper based. Later, it was conducted as computer based in 2015. After then, the choice has been left to the participating countries. PISA 2015 was applied as computer based in our country.

A total of 72 countries, 35 of which were OECD member countries, took part in PISA 2015 examination, which was the sixth of PISA application. Our country came 50th among 72 participating countries in PISA 2015 application. When the literature is gone through, it can clearly be seen that our mathematics literacy falls behind a great number of other countries [1, 2, 5, 6].

The definition of mathematics literacy focuses on active participation of students in mathematics. Besides, the individuals are supposed to use mathematical concepts, processes, and elements and tools so that they can carry out mathematical reasoning, and explain and predict the events. Mathematics literacy can be expressed as the individuals' skill of "formulizing", "using" and "interpreting" mathematics [7].

Mathematics literacy is important in respect to determine the levels of teenagers to be sufficiently ready in mathematics applications so that they can significantly solve the problems, which they come face to face, and can understand the crucial subjects. Besides, through evaluating the 15 years old students, in the post-lives of the teenagers, this provides them to with an early warning about how they can respond various situations that they will encounter related to mathematics [1, 4- 6].

In this study, it is aimed to determine the factors affecting mathematics literacy of students of 15 years of age in Turkey by radial based function the artificial neural networks (RBFN), which is one of the artificial neural networks.

2. Data Mining and Artificial Neural Networks

Data mining is a method, which helps the decision makers make reliable and rapid decisions by predicting the hidden relations, patterns and correlations between them in very large databases [8-11].

ANN, which is one of the methods of data mining, has been widely used in recent years since it is easily applicable to problems and has the ability to determine the high level non-linear relations that classical statistical methods cannot provide [12,13]. ANN has the property of being adapted to a non-linear device due to the fact that each processor has a calculation power and has memory with a very tiny structure. Therefore, ANN is a method which can be successfully employed in classification, clustering and prediction in order to solve numerous problems encountered in real life [14, 15].

ANNs are computer systems possessing properties such as discovering new information and ability to work countless variables by depending on the human brain operating principle [16]. ANN is formed with various connections of artificial neural cells and it is arranged in layer forms. According to structures, ANN is examined in two broad groups: feed-forward neural networks and recurrent neural networks [16].

2.1. Radial Basis Function Artificial Neural Network

RBFN, which is one of the feedforward neural networks, is prevalently used in many fields such as modelling and controlling non-linear systems [17].

RBFN is a method used to predict the relation between dependent and independent variables. In general, artificial neural networks are accepted as a strong method in learning the existing data and in a number of statistical feature of such as parameter prediction, classification and optimization. RBFNs possess the feature revealing complex relations between prediction variables and the inferences [18, 19, 20]. RBFNs have advantages since they have simple network architecture, and they are faster than traditional neural networks that are trained by back propagation, and they are more durable against the complex problems related to unstable inputs [20, 21].

The structure of RBFN consists of a hidden layer, an input layer, and a non-linear RBFN activation function and a linear output layer. The figure related to this definition is shown follow [21].

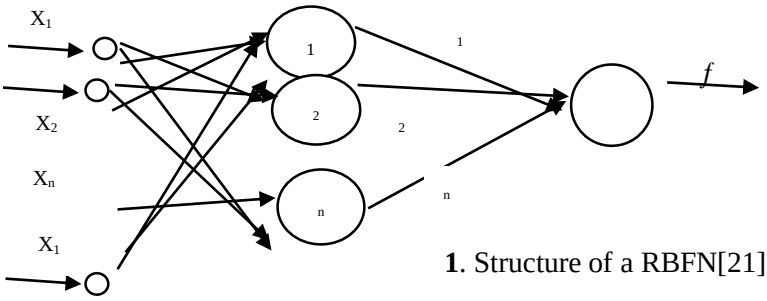

Figure 1. Structure of a RBFN[21]

Hidden layer inputs are combinations of input vector, $x = [x_1, x_2, \dots \dots . x_n]^T$. The incoming vectors are matched over radial based functions in each hidden layer. The output layer gives a y vector linearly combining the hidden node outputs so that the final output can be produced. The following formula is used to determine the network output:

$$y = f(x) = \sum_{i=1}^{k} \omega_i \, \phi_i(x) \quad (1)$$

Here, ω_i , $\phi_i(x)$, and k show ith central synaptic weight, ith radial function and total number of hidden nodes, respectively. Radial function is a multi-dimensional function defining the distance between pre-defined central vector and given input vector [21]. Radial functions are specific class functions which have increasing and decreasing values associated with distances from the class [22].

Normal Gaussian functions are generally used for radial based functions. The function is given below [23]:

$$\phi_i(x) = exp\left(-\frac{\|x-\mu_i\|^2}{2\sigma_i^2}\right) \quad (2)$$

Here, μ_i and σ_i show ith node centre and ith propagation width, respectively [21].

By employing Gaussian function, the formula that shows the network output is calculated as follows:

$$y = f(x) = \sum_{i=1}^{k} \omega_i \, exp\left(\frac{-\|x-\mu_i\|^2}{2\sigma_i^2}\right) \quad (3)$$

$$\lim_{[\![x]\!]\to\infty} \rho[\![x-\mu_i]\!] = 0 \quad (4)$$

Here, Gaussian basic function is accepted as central vector. In other words, it means that a RBFN possessing sufficient hidden neurons can approach any constant function with a large sensitive value clearance [21].

Most of the learning algorithms for RBFN start with either a pre-information use or previous experience use by utilizing pre-determined network structure. The result of network is generally either insufficiently or unnecessarily complex. The convenient network structure can be obtained merely via try and do wrong [24].

Normally, learning and designing of RBFN are realized in three sections. These are to calculate σ_i width and adjust the weights μ_i centre and σ_i. The width is fixed according to propagation of centres [20, 21].

$$\phi_i = e^{\left(\frac{h}{d^2}\|x-\mu_i\|^2\right), i=1,2,\dots..h} \quad (5)$$

Here, h shows the number of centres and d shows the maximum distances between the chosen centres.

Therefore;

$$\sigma = \frac{d}{\sqrt{2h}} \quad (6)$$

The base function is associated with the smallest width of RBFN and the smallest value of d; and it provides that to be more selective [20, 21].

3. Material

540 thousand students, attending schools of 72 participating countries, and representing 29 million students of 15 years of age, took part in PISA 2015 exam. 5895 students participated in PISA 2015 exam (MNE, 2016). In this study, information obtained from a total of 4422 (2165 (65%) of whom were boys and 2257 (51%) of whom were girls) was used since the data was cleared from unnecessary information. In the study, to determine the factors affecting PISA 2015 mathematics literacy, the dependent variable of mathematics literacy mean score of students, which was made categorical as three stages and students questionnaire belonging to PISA 2015 Turkey example; and as independent variables: anxiety, motivation and epistemological scales were used. The data used in the study were obtained from www.pisa.oecd.org, the official web site of OECD.

The descriptive statistics about independent variables used in this study are given in Table 1.

Table 1. Descriptive statistics about independent variables

Independent Variables	Categories	Frequency	%
Student International Grade	Grade 7	14	0.3
	Grade 8	68	1.5
	Grade 9	876	19.8
	Grade 10	3325	75.2
	Grade 11	133	3.0
	Grade 12	6	0.1
Gender	Female	2257	51
	Male	2165	49
What is the <highest level of schooling> completed by your mother?	High school	656	14.8
	Vocational/Technical High School	612	13.8
	Secondary school	877	19.8
	Primary school	1700	38.4
	Non-primary school graduate	577	13
What is the <highest level of schooling> completed by your father?	High school	719	16.3
	Vocational/Technical High School	872	19.7
	Secondary school	1204	27.2
	Primary school	1380	31.2
	Non-primary school graduate	247	5.2
In your home: A desk to study at	Yes	3795	85.8
	No	627	14.2
In your home: A room of your own	Yes	3210	72.6
	No	1212	27.4
In your home: A quiet place to study	Yes	3738	84.5
	No	684	15.5
In your home: A computer you can use for school work	Yes	3058	69.2
	No	1364	30.8
In your home: Educational software	Yes	1840	41.6
	No	2582	58.4
In your home: A link to the Internet	Yes	2827	63.9
	No	1595	36.1
In your home: Books to help with your school work	Yes	3741	84.6
	No	681	15.4
In your home: <Technical reference books>	Yes	1867	42.2
	No	2555	57.8
	Secondary school	70	1.6

Which of the following do you expect to complete?	Vocational/Technical High School	623	14.1
	High school	303	6.9
	College	236	5.3
	University /Graduate/ PhD	3190	72.1
Teachers called on me less often than they called on other students.	Never or almost never	1561	35.3
	A few times a year	880	19.9
	A few times a month	895	20.2
	Once a week or more	1086	24.6
Teachers graded me harder than they graded other students	Never or almost never	2485	56.2
	A few times a year	943	21.3
	A few times a month	660	14.9
	Once a week or more	335	7.6
Teachers gave me the impression that they think I am less smart than I really am.	Never or almost never	2639	59.7
	A few times a year	701	15.9
	A few times a month	622	14.1
	Once a week or more	460	10.4
Teachers disciplined me more harshly than other students.	Never or almost never	3058	69.2
	A few times a year	692	15.6
	A few times a month	354	8.0
	Once a week or more	318	7.2
Teachers ridiculed me in front of others.	Never or almost never	3319	75.1
	A few times a year	588	13.3
	A few times a month	281	6.4
	Once a week or more	234	5.3
Teachers said something insulting to me in front of others.	Never or almost never	3203	72.4
	A few times a year	654	14.8
	A few times a month	294	6.6
	Once a week or more	271	6.1
Number of <class periods> required per week in mathematics.	Low	890	20.1
	Medium	3517	79.5
	High	15	0.3
Turkish success status	Low	3177	71.8
	Medium	1232	27.9
	High	13	0.3
Learning time (minutes per week) - <Mathematics>	Low	989	22.4
	Medium	3342	75.6
	High	91	2.1

4. Findings

The descriptive statistics about independent variables used in this study are given in Table 1.

Table 1. Descriptive statistics about independent variables

Independent Variables	Categories	Frequency	%

Student International Grade	Grade 7	14	0.3
	Grade 8	68	1.5
	Grade 9	876	19.8
	Grade 10	3325	75.2
	Grade 11	133	3.0
	Grade 12	6	0.1
Gender	Female	2257	51
	Male	2165	49
What is the <highest level of schooling> completed by your mother?	High school	656	14.8
	Vocational/Technical High School	612	13.8
	Secondary school	877	19.8
	Primary school	1700	38.4
	Non-primary school graduate	577	13
What is the <highest level of schooling> completed by your father?	High school	719	16.3
	Vocational/Technical High School	872	19.7
	Secondary school	1204	27.2
	Primary school	1380	31.2
	Non-primary school graduate	247	5.2
In your home: A desk to study at	Yes	3795	85.8
	No	627	14.2
In your home: A room of your own	Yes	3210	72.6
	No	1212	27.4
In your home: A quiet place to study	Yes	3738	84.5
	No	684	15.5
In your home: A computer you can use for school work	Yes	3058	69.2
	No	1364	30.8
In your home: Educational software	Yes	1840	41.6
	No	2582	58.4
In your home: A link to the Internet	Yes	2827	63.9
	No	1595	36.1
In your home: Books to help with your school work	Yes	3741	84.6
	No	681	15.4
In your home: <Technical reference books>	Yes	1867	42.2
	No	2555	57.8
Which of the following do you expect to complete?	Secondary school	70	1.6
	Vocational/Technical High School	623	14.1
	High school	303	6.9
	College	236	5.3
	University /Graduate/ PhD	3190	72.1
	Never or almost never	1561	35.3

Teachers called on me less often than they called on other students.	A few times a year	880	19.9
	A few times a month	895	20.2
	Once a week or more	1086	24.6
	Never or almost never	2485	56.2
Teachers graded me harder than they graded other students	A few times a year	943	21.3
	A few times a month	660	14.9
	Once a week or more	335	7.6
Teachers gave me the impression that they think I am less smart than I really am.	Never or almost never	2639	59.7
	A few times a year	701	15.9
	A few times a month	622	14.1
	Once a week or more	460	10.4
Teachers disciplined me more harshly than other students.	Never or almost never	3058	69.2
	A few times a year	692	15.6
	A few times a month	354	8.0
	Once a week or more	318	7.2
Teachers ridiculed me in front of others.	Never or almost never	3319	75.1
	A few times a year	588	13.3
	A few times a month	281	6.4
	Once a week or more	234	5.3
Teachers said something insulting to me in front of others.	Never or almost never	3203	72.4
	A few times a year	654	14.8
	A few times a month	294	6.6
	Once a week or more	271	6.1
Number of <class periods> required per week in mathematics.	Low	890	20.1
	Medium	3517	79.5
	High	15	0.3
Turkish success status	Low	3177	71.8
	Medium	1232	27.9
	High	13	0.3
Learning time (minutes per week) - <Mathematics>	Low	989	22.4
	Medium	3342	75.6
	High	91	2.1

Within the context of the study, RBFN was employed. For the analyses performed in the study, SPSS and MS Excel programs were utilized. As a result of the analyses conducted, it was determined that the hidden layer activation function turned out to be softmax, while output layer activation function was identity. In the analysis of RBFN, accurate classification rate about predictions is shown in Table 2.

Table 2. Accurate classification rate according to RBFN

Model Building Method	**RBFN**
Target Field	Math achievement status
Number of Predictors Input	25
Model Accuracy	% 85.2
Misclassification Rate	% 14.8

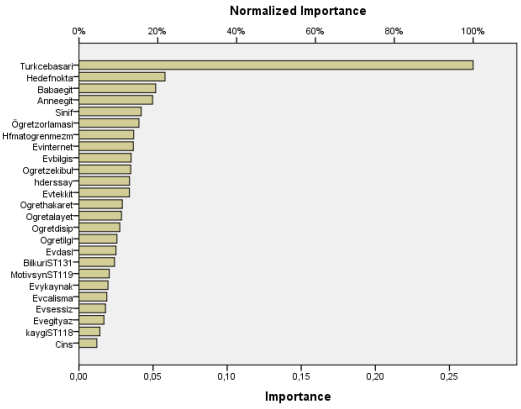

Figure 2. Normalized significance levels of variables according to RBFN

When Figure 2 is examined, it can be seen that the most important independent variable affecting the dependent variable is Turkish Language success level, and that the other variables are the Epistemological belief, weekly course number. It can be said that the other variables taking place in the model do not have much effect on dependent variable. The relative importance levels of all independent variables taking place in the model are given in Table 3.

Table 3. Significance levels of independent variables in RBFN architecture

Independent Variabl	Importance	Normalized Importance
Student International Grade	.042	% 15.8
Gender	.012	% 4.6
What is the <highest level of schooling> completed by your mother?	.050	% 18.7
What is the <highest level of schooling> completed by your father?	.052	% 19.5
In your home: A desk to study at	.019	% 7.1
In your home: A room of your own	.025	% 9.4
In your home: A quiet place to study	.018	% 6.7
In your home: A computer you can use for school work	.035	% 13.2
In your home: Educational software	.017	% 6.3
In your home: A link to the Internet	.037	% 13.8
In your home: Books to help with your school work	.020	% 7.4
In your home: <Technical reference books>	.034	% 12.8
Which of the following do you expect to complete?	.058	% 21.8
Teachers called on me less often than they called on other students.	.026	% 9.6

Teachers graded me harder than they graded other students	.040	% 15.2
Teachers gave me the impression that they think I am less smart than I really am.	.035	% 13.1
Teachers disciplined me more harshly than other students.	.028	% 10.4
Teachers ridiculed me in front of others.	.029	% 10.8
Teachers said something insulting to me in front of others.	.029	% 11.0
Number of <class periods> required per week in mathematics.	.034	% 12.8
Anxiety	.014	% 5.3
Motivation	.020	% 7.7
Epistemological Beliefs	.024	% 9.0
Turkish success status	.266	% 100.0
Learning time (minutes per week) - <Mathematics>	.037	% 13.9

It can be seem in Table 3 that the most significant variable is Turkish Language status with 100% standardized importance; just after comes the target aimed at school life with 21.8%, and then father education level with 19.5%, and then mother education level with 18.7%.

5. Discussion and Result

The aim of this study is to determine the factors affecting PISA 2015 Mathematics literacy by employing RBFN. In this study, where the factors affecting mathematics success of students are modelled by RBFN. Accuracy rate was found out to be 85.2%. When the literature is examined, in our country, no such a study like this one in which RBFN is used and about PISA data has not been encountered, yet [25, 26]. In their study, İnal and Turabik (2016) determined the accurate classification rate as 89.10% by multi-layer perceptron model; on the other hand, Tepehan (2011) found it as 78.6%. In addition, in which the multi-layer perceptron model was employed about students in [25-28].

The most vital factor having an influence on mathematics literacy was seen to be Turkish language success in this study; and the other variables that set significance were found to be the objective targeted in school life, father and mother education levels, respectively.

In the literature, it is known that there are a number of studies by using PISA data [1, 2, 5, 25, 29-31]. In parallel with our study, İnal and Turabik (2016) state that Turkish language success has an important effect on mathematics success. According to RBFN method, another significant variable having an effect on mathematics literacy is the variable called objective that the student target in his/her school life. When the literature has been the use of this variable has not been encountered. The other variable that RBFN method has found out is the father and mother education level variables. In parallel with the findings of our study, it is frequently seen that the father and mother education levels have had positive influences on the success of the student [1, 32-35]. In the literature, it is known that multi-layer perceptron model has been used in classification of students' success rather than artificial neural networks. As an alternative to ANN, in our study, the use of RBFN is suggested.

6. References

[1] Aksu G., Güzeller C.O. & Eser, M.T., (2017). Öğrencilerin Matematik Okuryazarlığı Performanslarının Aşamalı Doğrusal Model (HLM) ile İncelenmesi: PISA 2012 Türkiye Örneği. Türk Eğitim Derneği Eğitim ve Bilim, 42 (191), 247-266, 2017.

[2] Akyüz G. ve Pala M.N., (2010). Pisa 2003 sonuçlarına göre öğrenci ve sınıf özelliklerinin matematik okuryazarlığına ve problem çözme becerilerine etkisi. İlköğretim Online. 9(2). 668-678.

[3] Milli Eğitim Bakanlığı (MEB), (2016). PISA 2009 projesi ulusal ön raporu. (Online) http://odsgm.meb.gov.tr/test/analizler/docs/PISA/PISA2015_Ulusal_Rapor.pdf last retrieved on March 05, 2018.

[4] Türkan. A.. Üner S.S., Alcı. B., (2015). 2012 PISA Matematik testi puanlarının bazı değişkenler açısından incelenmesi. Ege Eğitim Dergisi. (16) 2: 358-372.

[5] Şahin, M.G., Yıldırım, Y., (2016). PISA 2012 Türkiye Örnekleminde Matematiksel Davranış ve Matematik Okuryazarlığını Etkileyen Değişkenlerin Çok Gruplu Hibrit Modelleme ile İncelenmesi. Eğitim ve Bilim. 41 (187): 181-198,

[6] Çelen. F.K., Çelik. A., Seferoğlu. S.S., (2016). Türk eğitim sistemi ve Pisa sonuçları. Akademik Bilişim'11 - XIII. Akademik Bilişim Konferansı Bildirileri, Malatya, 2016.

[7] OECD (2016). PISA 2015 mathematics framework. Pisa 2015 assessment and analytical framework: science. reading. mathematic and financial literacy. Paris: OECD Publishing. (Online) http://www.oecd.org/publications/pisa-2015-assessment-and-analytical-framework-9789264281820-en.htm

[8] Chen, S.Y. & Liu, X., (2004). The contribution of data mining to information science. Journal of Information Science, 30(6): 550–558.

[9] Fayyad, U., Piatetsky-Shapiro, G. & Smyth, P., (1996). From Data Mining to Knowledge Discovery in Databases. AI Magazine, 17(3).

[10] Larose, D.T., (2005). Discovering Knowledge in Data. A John Wiley & Sons, Inc., Publication, New Jersey.

[11] Shaw, M.J., Subramaniam, C., Tan, G.W. & Welge M.E., (2001) Knowledge management and data mining for marketing. Decision Support Systems, 1(31):127–137.

[12] Akbilgiç, O., (2011). Hibrit Radyal Tabanlı Fonksiyon Ağları İle Değişken Seçimi ve Tahminleme: Menkul Kıymet Yatırım Kararlarına İlişkin Bir Uygulama, İstanbul Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı Sayısal Yöntemler Bilim Dalı Doktora Tezi, İstanbul, 2011.

[13] Cganh, F.-J., Liang, J.-M. & Chen, Y.-C., (2001). Flood Forecasting Using Radial Basis Function Neural Networks. IEEE Transaction on Systems, Man, and Cybernetics Part C: Applications and Rewievs , 31 (4), 530-535, 2001.

[14] Priddy. K. L. & Keller. P. E., (2005). Artificial neural networks: An introduction. Washington: SPIE Press.

[15] Hamzaçebi, C., (2011). Yapay sinir ağları. Bursa, Ekin.

[16] Jain K.A. & Mao. J., (2018)Artificial Neural Network; A Tutorial, 1996. Online http://metalab.uniten.edu.my/~abdrahim/mitm613/Jain1996_ANN%20-%20A%20Tutorial.pdf last retrieved on February 10.

[17] Pislaru, C. & Shebani, A., (2014). Identification of Nonlinear Systems Using Radial Basis Function Neural Network, World Academy of Science, Engineering and Technology International Journal of Computer, Information, Systems and Control Engineering 8 No:9.

[18] Hastie, T., Tibshirani, R., & Friedman, J., (2009). The elements of statistical learning. New York, NY, USA: Springer.

[19] Kayri M. & Çokluk Bökeoğlu Ö., (2016). Examining Factors of Academic Procrastination Tendency of University Students by using Artificial Neural Network. International Journal of Computer Trends and Technology, 34(1), 1-8.

[20] Kayri. M., (2015). An ıntelligent approach to educational data: performance comparison of the multilayer perceptron and the radial basis function artificial neural networks. Educational Sciences: Theory & Practice. 15(5). 1247-1255.

[21] Chen, J., Zhao, P., Liang, H.& Mei, T., (2014). Motion planning for autonomous vehicle based on radial basis function neural network in unstructured environment. Sensors, 14, 17548–17566.

[22] Santos, R.B., Rupp M., Bonzi S.J. & Fileti AM.F., (2013).Comparison Between Multilayer Feedforward Neural Networks and a Radial Basis Function Network to Detect and Locate Leaks in Pipelines Transporting Gas, Chemical Engineering Transactions, 32.

[23] Chadha, A.N., Nirmal, J.N. & Zaveri, M.A., (2014). A Comparison of Multi-layer Perceptron and Radial Basis Function Neural Network in the Voice Conversion Framework, InternationalConference on Advancesin Computing, Communicationsand Informatics (ICACCI). 24-27 September 2014.Delhi, India.

[24] Billings, S.A. & Zheng, G.L., (1994). Radial Basis Function Network Configuration Using Genetic Algorithms. Research Report. ACSE Research Report 521. Department of Automatic Control and Systems Engineering.

[25] İnal H. & Turabik T. (2016). Matematik Başarısını Etkileyen Bazı Faktörlerin Yordama Gücünün Yapay Sinir Ağları İle Belirlenmesi. Uşak Üniversitesi Eğitim Araştırmaları Dergisi, 3(1), 23-50.

[26] Tepehan, T., (2011). Türk öğrencilerinin PISA başarılarının yordanmasında yapay sinir ağı ve lojistik regresyon modeli performanslarının karşılaştırılması (doktora tezi). Hacettepe Üniversitesi, Ankara.

[27] Çırak, G. & Çokluk, Ö., (2013). Yükseköğretimde öğrenci başarılarının sınıflandırılmasında yapay ağları ve lojistik regresyon yöntemlerinin kullanılması. Mediterranean Journal of Humanities, 3(2), 71-79.

[28] Tosun, S., (2007). Sınıflandırmada yapay sinir ağları ve karar ağaçları karşılaştırması: Öğrenci başarıları üzerine bir uygulama (doktora tezi). İstanbul Teknik Üniversitesi, İstanbul.

[29] Anıl, D., (2009). Uluslararası öğrenci başarılarını değerlendirme programı (Pisa)'nda Türkiye'deki öğrencilerin fen bilimleri başarılarını etkileyen faktörler. Eğitim ve Bilim Dergisi, 34 (152), 87-100.

[30] Aksu G. & Güzeller C.O., (2016). Pisa 2012 Matematik Okuryazarlığı Puanlarının Karar Ağacı Yöntemiyle Sınıflandırılması: Türkiye Örneklemi. Eğitim ve Bilim Dergisi, 41(185), 101-122.

[31] Azapağası İlbağı E. & Akgün L., (2012). Pisa 2003 öğrenci anketine göre 15 yaş grubu öğrencilerinin tutumlarının incelenmesi. Western Anatolia Journal of Educational Science. 3(6), 67-90.

[32] Dursun, Ş.& Dede, Y., (2004). Öğrencilerin matematikte başarısını etkileyen faktörler: matematik öğretmenlerinin görüşleri bakımından. Gazi Eğitim Fakültesi Dergisi, 24 (2), 217-230.

[33] Gürsakal, S., (2009). PISA 2009 Öğrenci başarı düzeylerini etkileyen faktörlerin değerlendirilmesi. Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi. 17(1), 441-452.

[34] Mutluer, C. & Büyükkıdık, S., (2017). PISA 2012 verilerine göre matematik okuryazarlığının lojistik regresyon ile kestirilmesi. Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi, 46: 97-112, 2017.

[35] Uysal E. & Yenilmez K., (2011). Sekizinci sınıf öğrencilerinin matematik okuryazarlığı düzeyi. Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi, 12(2), 1-15.