

Analysis on Students' Learning Habits: Identifying the Contributory Factors of Learning During the Covid-19 Pandemic Using Radial Basis Function (RBF)

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Abstract: The Artificial Neural Network (ANN) is an Artificial Intelligence technique that offer many benefits including the ability to process a vast amount of data, the ability to learn from experiences, and the good generalization capability. It was invented based on the concept of imitation of the human brain and built up of nodes that are like human neurons. The Radial Basis Function (RBF) is one of the established types of ANN. Considering the advantages and great performance of the RBF, this study aims to investigate the contributory factors of students' learning habits during the Coronavirus Disease 2019 (or known as COVID-19) pandemic using RBF. Responses from a total of 420 respondents were collected from Vietnamese students' learning habits during the COVID-19 pandemic dataset that was established from the questionnaires distributed in the period of 7th February 2020 to 28th February 2020. Fifteen independent variables were used as the input for the RBF network which is based on the 15-9-1 structure. Based on the experiment conducted, the implementation of the RBF model was found to be fair and effective with the small number of Sum of Square Error (SSE) and Relative Error (RE) produced. It could also be concluded that the most contributing factor of students' learning habits during the COVID-19 pandemic is the learning hours per day for self-learning before the pandemic.

Keywords: Covid-19, learning habits, Artificial Neural Network (ANN), Radial Basis Function (RBF).

1. Introduction

Online learning has started to grow in many educational institutions due to its flexibility, mobility, and effectiveness since the early stage of the 21st century [1-3]. Also, online learning or e-learning is not something new in higher educational institutions as this approach has been implemented in universities' distance learning process. However, recently, online learning has turned out to be an essential activity among students due to the closure of educational institutions due to the COVID-19 pandemic, thus, possible opportunities related to online learning have been explored [4]. Recently, people all over the world are struggling to cope with the new normal since COVID-19 hits. Hence, the implementation of normal learning has shifted from the traditional physical classroom into a virtual classroom [5]. Due to that, enormous educational institutions worldwide have conducted online and resulting direction towards studying student's learning habits.

Students learning habits are very essentials as they affects student's attitude, knowledge, and performance [6]. It is mentioned in [7] that learning habits encompass mental, physiological, natural habits, and the preferred ways of absorbing, processing, and retaining new knowledge and skills. Learning habits reflect student's usual act of studying and serve to direct the learner's cognitive processes during learning [2]. This process includes activities that deal with time management, goal setting, appropriate study environment, using appropriate note-taking strategies, choosing main ideas, and organization [2][8]. Studies in [1][2] mentioned that there is a positive correlation between learning habits and learner performance. Hence, it is very important to analyse student's learning habits as it is one of the main factors affecting their performance in learning.

The Artificial Neural Network (henceforth, ANN) is an Artificial Intelligence technique that has many benefits including the ability to process a vast amount of data, the ability to learn from experiences, and the good generalization capability [9]. Initially, ANN was invented based on the concept of imitation of the human brain [10]. ANN is a built up of nodes that are like human neurons. All these nodes are interconnected to one another and build up a network. One of the established types of the neural network is based on the Radial Basis Function (RBF) network.

There are many available works related to the RBF network model. For instance, RBF is vastly applied in the engineering sector and it produces promising results. Among of the examples are the application of RBF modelling submerges breakwaters [11], monitoring tunnel ventilating system [12], estimating reinforce building's seismic damage level [13], and wind energy conversion system [14]. Meanwhile, for the prediction task, RBF is applied in estimating the chemical structure of aluminium foam [15], predicting factors that

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contribute to COVID-19's death and spread [16-17], predicting and recognizing human activity [18], and as well in predicting construction cost [19].

Considering the advantages and great performance of Radial Basis Function (RBF) ANN, this study aims to investigate the contributory factors of students' learning habits during the COVID-19 pandemic. The implementation of RBF is expected to give insights and understandings on the factors that contribute to online learning habits among students. The structure of this paper is as the following: Section 2 discusses the data background and followed by Section 3 which elaborates on the methodology. Next, results and discussions are presented in Section 4 while Section 5 is the conclusion.

2. Data background

A dataset of Vietnamese students' learning habits during the COVID-19 pandemic [20] was retrieved from the Research Gate's open source. This dataset was established from the questionnaires distributed in the period of 7th February 2020 to 28th February 2020. It comprised of three major groups of questions which are (1) student's demographic, (2) student's learning habits, and (3) student's perception of self-learning during the school closure. This dataset was composed of 460 responses from the secondary students in grades 6-12. However, only 420 data were valid after the process of data cleaning. The descriptive statistics of the dataset is illustrated in Table 1 as follows.

Table 1: Descriptive Statistics [20]

<i>Learning hours</i>	<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error</i>	<i>Max</i>	<i>95% Confidence Interval for Mean</i>		<i>Min</i>	
						<i>Lower Bound</i>	<i>Upper Bound</i>		
(1) Student's demographic									
Father's job	STEM-related	141	1.59	.687	.058	3	1.47	1.70	1
	Social Science	172	1.64	.724	.055	3	1.53	1.75	1
	Free	73	1.51	.710	.083	3	1.34	1.67	1
	Others	34	1.35	.544	.093	3	1.16	1.54	1
	Total	420	1.58	.699	.034	3	1.51	1.64	1
University Entrance Exam	A	52	1.48	.641	.089	3	1.30	1.66	1
	A1	64	1.84	.672	.084	3	1.68	2.01	1
	B	23	1.70	.559	.117	3	1.45	1.94	1
	C	22	1.41	.734	.157	3	1.08	1.73	1
	D	187	1.55	.727	.053	3	1.44	1.65	1
	Other	72	1.50	.671	.079	3	1.34	1.66	1
	Total	420	1.58	.699	.034	3	1.51	1.64	1
	Self-evaluation	Below average	7	1.14	.378	.143	2	.79	1.49
Average		109	1.41	.596	.057	3	1.30	1.53	1
Good		251	1.62	.702	.044	3	1.53	1.70	1
Excellent		53	1.77	.824	.113	3	1.55	2.00	1
Total		420	1.58	.699	.034	3	1.51	1.64	1
English proficiency	Below average	35	1.43	.655	.111	3	1.20	1.65	1
	Average	135	1.46	.620	.053	3	1.35	1.56	1
	Good	191	1.62	.721	.052	3	1.52	1.73	1
	Excellent	59	1.78	.767	.100	3	1.58	1.98	1
	Total	420	1.58	.699	.034	3	1.51	1.64	1
(2) Student's learning habits									
Learning time before COVID-19	Under 4 h	312	1.38	.560	.032	3	1.32	1.44	1
	From 4 h to 7 h	93	2.09	.732	.076	3	1.94	2.24	1
	Over 7 h	15	2.53	.743	.192	3	2.12	2.94	1
	Total	420	1.58	.699	.034	3	1.51	1.64	1

(3) Student's perceptions of self-learning during the school closure

	N	Range	Min	Max	Mean		Std. Deviation
					Statistics	Std. Error	
I can ensure my learning progress	420	4	1	5	3.90	.047	.965
I can maintain my learning habits	420	4	1	5	3.88	.045	.926
My parents show me it is necessary	420	4	1	5	3.73	.050	1.019
I am motivated for self-learning	420	4	1	5	3.44	.049	.998
I have good concentration skills	420	4	1	5	3.36	.047	.970
I have support from my family	420	4	1	5	3.35	.053	1.090
I have an effective learning environment	420	4	1	5	3.55	.050	1.034
I can define my daily learning objectives	420	4	1	5	3.44	.050	1.017
I have various learning resources	420	4	1	5	3.66	.048	.983
I communicate and collaborate with my friends about learning	420	4	1	5	3.21	.055	1.129

3. Research methodology

This section discusses the methodology used in this study that aims to assess the performance of the RBF network in investigating the contributory factors of students' learning habits during the COVID-19 pandemic.

A. Radial Basis Function (RBF) Network

The RBF network is a feed-forward neural network type. It is built of three different layers which are the input layer, the hidden layer, and the output layer [11]. The representation of input pattern used in RBF network is based on the middle layer given with a set of input units. The use of the activation functions at this middle layer is important for the purpose to characterize each of the input units used in the network.

RBF is highly successful in function approximation and pattern recognition [21]. Moreover, it is also known that the RBF structure offers a simple layout, rapid convergence speed and more important is to be able to perform universal approximation [11][12][15]. The RBF network is widely used due to its advantages such as excellent generalization, easy structure, high input noise tolerance and online learning capabilities [16][17]. An example of a basic structure of RBF with one hidden layer is demonstrated in Fig 1.

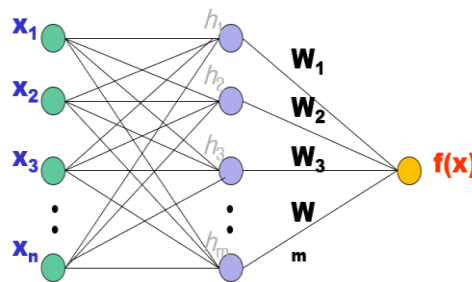


Figure 1: RBF network with one hidden layer [22]

The radial basis function used in the network depends on the strategy of the network itself. The approximation function with linear combination of Radial Basis function is expressed as in Equation 1.

$$F(x) = \sum w_i h(x) \tag{1}$$

Where (hx) is mostly the Gaussian functions. The RBF neuron activation function is slightly different and is typically written as in Equation 2.

$$f(x) = \sum w_j h_j(x)$$

$$h_j(x) = \exp(-\frac{(x-c_j)^2}{r_j^2}) \quad (2)$$

Where c_j is the centre of a region and r_j is the width of the receptive field.

4. Result and analysis

This section discusses the results obtained from the experiment conducted. The dataset of the Vietnamese students was run using SPSS 13. The case processing summary for RBF is displayed in Table 2.

Table 2: Case Processing Summary for RBF Model

		<i>N</i>	<i>Percent</i>
Sample	Training	304	72.4%
	Testing	116	27.6%
Valid		420	100.0%
Excluded		0	
Total		420	

Based on Table 2, the dataset used in this study was divided into two groups; which are training and testing. The training set for RBF is 72.4% (304/420) and the testing set is 27.6% (116/420). The overall data from the dataset is $N = 420$ and there is no excluded data reported.

There were fifteen covariates used in the network which are *fa_job*, *exam*, *Self_evaluation*, *English*, *Lh_before_Cov*, *nec_prog*, *nec_habit*, *nec_parent*, *eff_moti*, *eff_con*, *eff_supp*, *eff_env*, *eff_obj*, *eff_resource*, and *eff_friend*. Table 3 shows the descriptions of the covariates used in this study.

Table 3: Covariates' Descriptions

<i>Input layer</i>	<i>Covariates</i>	<i>Descriptions</i>
1	<i>fa_job</i>	What is your father's job?
2	<i>exam</i>	What subject group do you intend to take for the university entrance exam?
3	<i>Self_evaluation</i>	How do you evaluate your performance, regarding your selected subject group?
4	<i>English</i>	How do you evaluate your English capability?
5	<i>Lh_before_Cov</i>	Before COVID-19, how many hours did you spend per day for self-learning?
6	<i>nec_prog</i>	I can assure my learning progress
7	<i>nec_habit</i>	I can maintain my learning habit
8	<i>nec_parent</i>	My parents show me it is necessary
9	<i>eff_moti</i>	I am motivated for self-learning
10	<i>eff_con</i>	I have proper concentration skills
11	<i>eff_supp</i>	I have support from my family
12	<i>eff_env</i>	I have an effective learning environment
13	<i>eff_obj</i>	I can define my daily learning objectives
14	<i>eff_resource</i>	I have various learning resources
15	<i>eff_friend</i>	I communicate and collaborate with my friends about learning

These fifteen covariates acted as the input for the RBF network. The activation function used in the network is Softmax and there is one dependent variable which is *Lh_in_Cov*. To simplify the architecture, it could be addressed as the 15-9-1 RBF network architecture as portrayed in Fig 2.

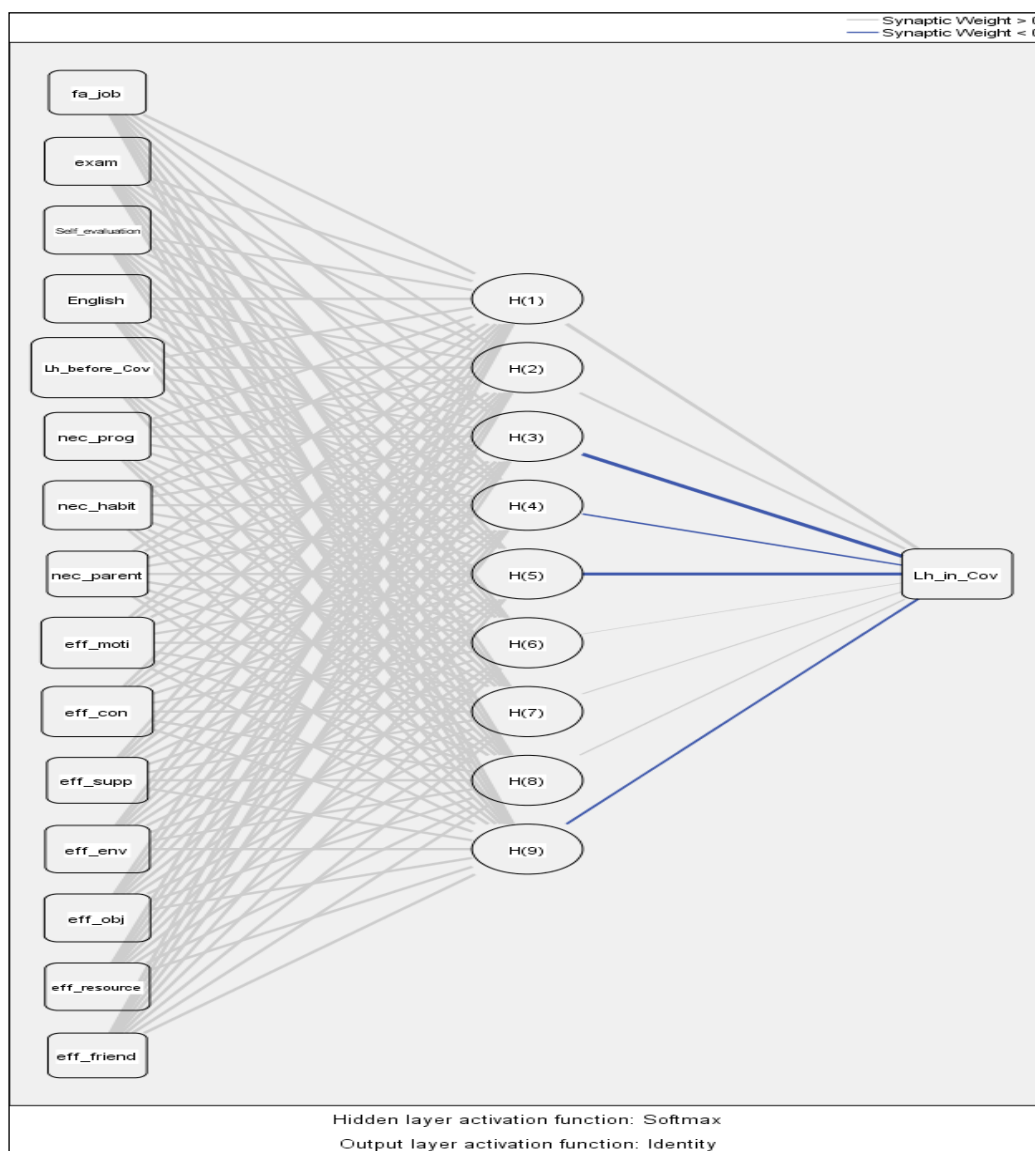


Figure 2: RBF Network Architecture

Based on the illustration of the RBF network architecture in Fig 2, this network is composed of 15 inputs with one hidden layer with 9 nodes. Softmax is used as the hidden layer activation function. Hence, the target output of this network is the learning hours during COVID-19 (Lh_in_Cov). The identity (purelin) function is used as the activation function from the hidden layer to the output layer and the default error function applied is the sum of squares (SSE). SSE is the sum of differences between each observation group mean, and it is used to indicate the variation within a cluster. Hence, it can be concluded that the smaller the SSE, the lesser the variation between the clusters.

To simplify the configuration of the network, it is addresses as the 15-9-1 RBF network structure. Consequently, Table 4 tabulates a summary from the RBF network while Table 5 demonstrates the independent variables' importance.

Table 4: RBF Model Summary

<i>Training</i>			<i>Testing</i>	
<i>Sum of Squares Error</i>	<i>Relative Error</i>	<i>Training Time</i>	<i>Sum of Squares Error</i>	<i>Relative Error</i>
121.054	.799	0:00:04.68	43.037 ^a	.630

Dependent Variable: Lh_in_Cov

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a. The number of hidden units is determined by the testing data criterion: The "best" number of hidden units is the one that yields the smallest error in the testing data.

Table 5: Independent Variables' Importance

<i>Variables</i>	<i>Importance</i>	<i>Normalized Importance</i>
What is your father's job?	.032	19.8%
What subject groups do you intend to take for the university entrance exam?	.063	38.9%
How do you evaluate your performance regarding your selected subject group?	.065	40.5%
How do you evaluate your English capability?	.065	40.7%
Before COVID-19, how many hours did you spend per day for self-learning?	.161	100.0%
I can assure my learning progress	.064	39.8%
I can maintain my learning habit	.072	44.7%
My parents show me it is necessary	.044	27.7%
I am motivated for self-learning	.088	54.9%
I have proper concentration skills	.081	50.5%
I have support from my family	.045	28.1%
I have an effective learning environment	.058	36.4%
I can define my daily learning objectives	.064	39.5%
I have various learning resources	.059	36.8%
I communicate and collaborate with my friends about learning	.038	23.4%

Table 5 tabulates the independent variables' importance for the RBF network constructed in this study. It is stated that the five most influential factors based in this study are Lh_before_Cov (100), eff_moti (54.9), eff_con (50.5), nec_habit (44.7), and English (40.7). Fig 3 portrays the normalized importance of the independence variables in the graph representation.

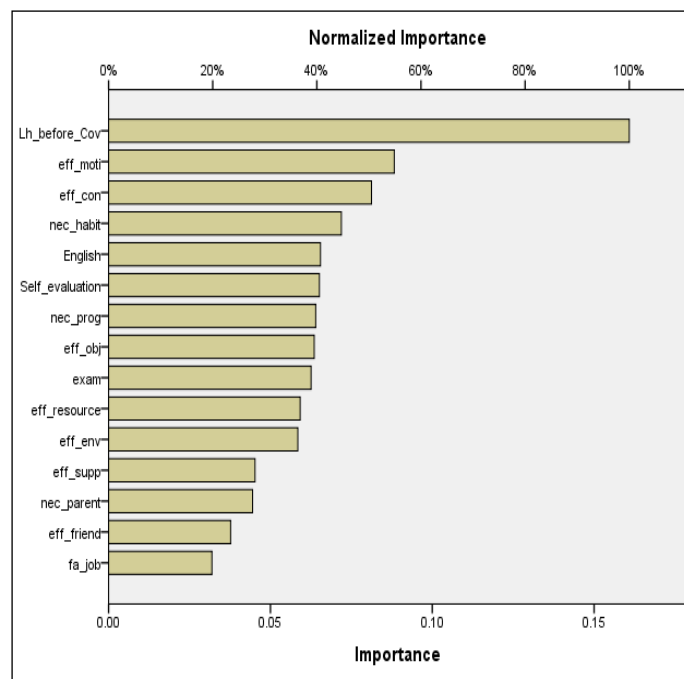


Figure 3: RBF Network Architecture

As previously mentioned, the performance evaluation was conducted on the developed RBF network model using the Sum of Square Error (SSE) and Relative Error (RE). Table 6 and Table 7 demonstrate the SSE and RE for the RBF network model, respectively.

Table 6: SSE of ANN RBF Model

<i>Rescaling of Covariates</i>	<i>Radial Basis Neural Network Activation Function for Hidden Layer</i>	
	<i>Normalized Radial Basis Function</i>	<i>Ordinary Radial Basis Function</i>
Standardized	43.037^a	58.425 ^a
Normalized	56.313 ^a	40.318^a
Adjusted	54.092 ^a	52.350 ^a
Normalized		
None	53.056 ^a	69.189 ^a

Based on the SSE results tabulated in Table 6, it can be observed that the Standardized rescaling method produced using the Normalized Radial Basis Function is lower than the Ordinary Radial Basis Function. However, in the Normalized rescaling method, the Ordinary Radial Basis Function achieved 40.318, as compared to the Normalized Radial Basis Function.

Next, for RE, the Normalized Radial Basis Function achieved 0.630 and 0.893 for the Standardized and Normalized rescaling factors, respectively. For the Ordinary Radial Basis Function, the Standardized and Normalized scaling factors obtained are 0.872 and 0.898, respectively. Hence, it can be concluded that the RBF model is stable for both Normalized Radial Basis Function and Ordinary Radial Basis Function. In addition, these promising SSE and RE values obtained reflect that the model is useful in identifying the most contributory factor for students' learning habits during the COVID-19 pandemic.

5. Conclusion

This paper presented a study to investigate the contributory factors of students' learning habits during the COVID-19 pandemic using Radial Basis (RBF) network. Vietnamese secondary students' dataset was used in which it composed of a total of 420 respondents. There were fifteen independent variables used as the input for the RBF network and the network was based on the 15-9-1 structure. Based on the result obtained from the experiment, it was observed that the most contributory factor in students' learning habits during the COVID-19 pandemic was the learning hours before the COVID-19 pandemic (Lh_before_Covid). This means that students' learning behaviour before the pandemic was a necessity in maintaining their learning behaviour during the pandemic. It is also concluded that the implementation of the RBF model was fair and effective with the small number of SSE and RE produced from the developed model. On a different side, this study contributes towards the investigation of the contributory factors in students' learning habits during the pandemic. In the future, it is suggested that the exploration of the contributory factors is further investigated as it is important in preparing educational institutions and society for a better learning environment.

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