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PREDICTION OF STUDENTS' SCIENCE ACHIEVEMENT: AN APPLICATION OF MULTIVARIATE ADAPTIVE REGRESSION SPLINES AND REGRESSION TREES

Serpil Kilic Depren

Abstract. *Turkey is ranked at the 54th out of 72 countries in terms of science achievement in the Programme for International Student Assessment (PISA) survey conducted in 2015, which is a very big disappointment for that country. The aim of this research was to determine factors affecting Turkish students' science achievements in order to identify the improvement areas using PISA 2015 dataset. To achieve this aim, Multivariate Adaptive Regression Splines (MARS) and Classification and Regression Trees (CART) approaches were used and these approaches were compared in terms of model accuracy statistics. Since Singapore was the top performer country in terms of science achievement in PISA 2015 survey, the analysis results of Turkey and Singapore were compared to each other to understand the differences. The results showed that MARS outperforms the CART in terms of measuring the prediction of students' science achievement. Furthermore, the most important factors affecting science achievements were environmental optimism, home possessions and science learning time (minutes per week) for Turkey, while the index of economic, social and cultural status, environmental awareness and enjoyment of science for Singapore.*

Keywords: *higher education, machine learning algorithms, PISA, science achievement.*

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Introduction

There are many studies examining factors affecting academic (mathematics, science or reading) achievements using different statistical methods. Programme for International Student Assessment (PISA), Trends in International Mathematics and Science Study (TIMSS) and Progress in International Reading Literacy Study (PIRLS) help countries to identify the areas that need to be improved and to increase their ranking among other countries.

In the literature, researchers generally used PISA, TIMSS and PIRLS studies' dataset in order to determine the factors affecting students' achievement (Carnoy, Khavenson, & Ivanova, 2015; Sebastian, Moon, & Cunningham, 2016; Rutkowski, Rutkowski, Wild, & Burroughs, 2017). Von Davier, Hao, Liu and Kyllonen (2017) developed the collaborative problem-solving framework behind ETS Collaborative Science Assessment Prototype (ECSAP), which was based on PISA 2015 survey and Assessment and Teaching of the 21st Century Skills (ATC21S) frameworks. Sheldrake, Mujtaba, and Reiss (2017) analyzed PISA 2006 and PISA 2015 Science Tests scores for students in England.

In addition to classical approaches, some data mining algorithms have been used in the educational area to assess or compare the performance of students in terms of science, mathematics or reading achievements. Kabakchieva's (2013) study collected data from university management using methods such as J48, Naïve Bayes, BayesNet, k-NN and JRip algorithms. J48 and JRip were found to be more reliable and demonstrated better performance than the other methods. Shariri, Husain, and Rashid studied the predicting of students' performance in academic institutions in Malaysia, which was proposed to improve achievement using the Decision Tree, Neural Network, Naïve Bayes, k-NN and SVM algorithms (Shariri, Husain, & Rashid, 2015). The result on prediction accuracy has been of the highest value in the Neural Network by (98%) followed by the Decision Tree, SVM, k-NN and Naïve Bayes, respectively. The study of Martinez Abad and Chaparro Caso López (2017) investigated the factors of students, social and schools by using classification techniques. As mentioned previously, the results showed that student-related variables were the most efficient factors for academic success (Cortez & Silva, 2008). Using data mining techniques, however, past evaluation had an influence on student performance, and the factors of parents' education and job, and alcohol consumption were also other important variables regarding success.

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Problem of Research

The government of Turkey has a goal to reach a high level of education in their 10th development plan published in 2014. Thus, the government has been implemented many major improvements in the educational area to increase the quality of the education since 2010. However, Turkey does not take part in the highest performing countries in all PISA surveys. Turkey is ranked 54th out of 72 countries in terms of science achievement in 2015, which is very disappointing for Turkey. In order to reach a higher level of Turkish educational performance, factors that have a significant effect on the students' achievement should be identified. Then, Turkey should focus on the areas of development by setting a good reference point. In terms of science achievement, the most successful country of PISA 2015 survey is Singapore, which is taken as a reference point for Turkey.

Researchers studied on determining factors affecting students' achievement using many different techniques in order to reach a high level of estimation accuracy. In the literature, there are many types of research about modeling students' achievement, especially on classification and prediction based techniques. However, it generally does not distinguish clearly which method has better performance in terms of estimation accuracy, because there are minor differences between the results of techniques used. Despite the fact that researchers may provide important contributions to educational studies using many statistical techniques, MARS and CART algorithms have rarely been used in this field. Using PISA 2015 survey, MARS and CART methods are analyzed and compared their performance in this research.

Research Focus

The research focused on determining factors that affect science achievement of Turkish students. It specifically tried to find answers to following questions:

1. What are the significant factors that have a significant impact on students' science achievement?
2. Which method has the best prediction performance based on the goodness of fit criteria?

When these questions are answered, following possible actions can be implemented for increasing students' science achievement:

1. The most significant factors of science achievement are determined. Thus, educational policymakers can focus on these factors and prioritize educational policies to increase science achievement.
2. The method with the best performance in terms of classification and prediction between two algorithms used in the research is determined. Thus, this research can be a good reference for further researches in order to choose the best model for achievement prediction in the educational areas.

Methodology of Research

General Background

PISA is an international survey which has been held by the Organization Economic for Co-Operation and Development (OECD) since 2000. It is conducted every three years in order to measure how well students can make a prediction using what they have learned and can interpret their knowledge about the subject that they are unfamiliar. Thus, it can help countries to implement the necessary educational policies. In all PISA surveys, the 15-year-old students' knowledge of mathematics, science and reading are questioned. Approximately 550,000 students from 72 countries participated in PISA 2015 survey. Students took two-hour computer-based tests. Test items were multiple-choice or open-ended questions. Students also answered many questions about themselves, their homes, their schools and learning experience. Fieldwork of the survey was made during 2015 and two-step stratified sampling technique was used in the survey (MEB, 2016; OECD, 2018).

Sample

The top-performing country is Singapore in PISA 2015 survey in terms of science achievement. Thus, Turkey and Singapore dataset were taken into consideration in order to determine the main differences between these countries in terms of science achievement and other factors such as socio-economic cultural status and wealth etc. 6,115 students from Singapore and 5,895 students from Turkey participated in the PISA 2015 study. Since the missing

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values of the variables used in this research, 4,735 Singaporean and 4,569 Turkish students were used in this analysis.

In PISA surveys, there are three basic question sets: student, school, and teacher questionnaire. In this research, only student-related factors affecting students' achievement were examined.

In the student questionnaire, there are both single (such as gender) and indexed (such as index of economic, social and cultural status and home possessions) variables. The indexed variables are designed as the Item-Response Theory (MEB, 2016).

The student-related factors used in the analysis are given in Table 1.

Table 1. Variables examined in the analysis.

Indexed Variable Name	Description	Question no. in PISA Questionnaire
GENDER	GENDER	ST04
CULTPOSS	CULTURAL POSSESSIONS AT HOME	ST011, ST012
HEDRES	HOME EDUCATIONAL RESOURCES	ST011
WEALTH	FAMILY WEALTH	ST011, ST012
ICTRES	ICT RESOURCES	ST011, ST012
HOMEPOS	HOME POSSESSIONS	ST011, ST012, ST013
ESCS	INDEX OF ECONOMIC, SOCIAL AND CULTURAL STATUS	ST005, ST006, ST007, ST008, ST011, ST012, ST013, ST014, ST015
BELONG	SENSE OF BELONGING TO SCHOOL	ST034
UNFAIRTCHR	TEACHER FAIRNESS	ST039
MMINS	MATHEMATICS LEARNING TIME (MINUTES PER WEEK)	ST059, ST061
SMINS	SCIENCE LEARNING TIME (MINUTES PER WEEK)	ST059, ST061
COOPERATE	ENJOY COOPERATION	ST082
CPSVALUE	VALUE COOPERATION	ST082
ENVAWARE	ENVIRONMENTAL AWARENESS	ST092
ENVOPT	ENVIRONMENTAL OPTIMISM	ST093
JOYSCIE	ENJOYMENT OF SCIENCE	ST094
INTBRSCI	INTEREST IN BROAD SCIENCE TOPICS	ST095
DISCLISCI	DISCIPLINARY CLIMATE IN SCIENCE CLASSES	ST097
IBTEACH	INQUIRY-BASED SCIENCE TEACHING AND LEARNING PRACTICES	ST098
TEACHSUP	TEACHER SUPPORT IN A SCIENCE CLASSES	ST100
TDTEACH	TEACHER-DIRECTED SCIENCE INSTRUCTION	ST103
PERFEED	PERCEIVED FEEDBACK	ST104
ADINST	ADAPTION OF INSTRUCTION	ST107
INSTSCIE	INSTRUMENTAL MOTIVATION	ST113
ANXTEST	TEST ANXIETY	ST118
MOTIVAT	ACHIEVEMENT MOTIVATION	ST119
EMOSUPS	PARENTS EMOTIONAL SUPPORT	ST123
SCIEEFF	SCIENCE SELF-EFFICACY	ST129
EPIST	EPISTEMOLOGICAL BELIEFS	ST131
SCIEACT	SCIENCE ACTIVITIES	ST146
AUTICT	STUDENTS' PERCEIVED AUTONOMY RELATED TO ICT USE	IC015
COMPICT	STUDENTS' PERCEIVED ICT COMPETENCE	IC014
ENTUSE	ICT USE OUTSIDE OF SCHOOL LEISURE	IC008
HOMESCH	ICT USE OUTSIDE OF SCHOOL FOR SCHOOLWORK	IC010
ICTHOME	ICT AVAILABLE AT HOME INDEX	IC001
ICTSCH	ICT AVAILABLE AT SCHOOL INDEX	IC009
INTICT	STUDENTS' ICT INTEREST	IC013
SOIAICT	STUDENTS' ICT AS A TOPIC IN SOCIAL INTERACTION	IC016
USESCH	USE OF ICT AT SCHOOL IN GENERAL	IC011

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In Table 1, gender was defined as a categorical variable (0-female, and 1-male); the other variables were defined as index variables.

Instrument and Procedures

CART is based on a recursive partitioning method, which is used for predicting categorical independent variables (classification) and continuous dependent variable (regression). CART, which is a common decision tree algorithm, was firstly introduced in 1984 (Breiman, Friedman, Olshen, & Stone, 1984). CART is sensitive to outliers and missing data.

Using all the independent variables, CART is constructed by splitting subsets to compose of two child knots repeatedly. The impurity or diversity measures such as Gini, least-squared deviation, towing and ordered twoing are used for choosing the best predictor. According to the goal of the study, the desire is to obtain subgroups as homogeneous as possible (Breiman, Friedman, Olshen, & Stone, 1984; Türe, Tokatlı, & Kurt, 2009).

MARS was first introduced by Jerome H. Friedman (1991) and can be defined as follows:

$$\hat{f}(x) = \beta_0 + \sum_{m=1}^{M} \beta_m \prod_{k=}^{K_m}$$

(1)

M, K_m and βs are the number of basis functions, the number of knots and the parameters, respectively in Equation 1. s_{km} takes on the value of either 1 or -1. v(k,m) and t_{km} indicate the label of the independent variable and the knot location, respectively.

The general MARS method is constructed in a two-step process. Firstly, all the possible basis functions produced using independent variables are added and found knots to improve predicting in the forward stepwise process. This continues until the basis functions reach a predetermined maximum number. In a backward stepwise process, the best model is also reached by eliminating some basis functions from the most complex model to prevent overfitting. Generalized Cross-Validation (GCV) is used to measure the quality goodness of fit that penalizes large numbers of basis functions and seems to reduce the probability of overfitting. When the variable is excluded from the model, the GCV value is re-calculated and compared to the previous GCV value in order to measure the variable importance. These values are on a scale of 0-100. If the GCV value has the highest decrease, it will score 100, which is the most important variable. MARS has been commonly used by researchers for the following advantages: (1) MARS is flexible in specifying the nonlinear relationships between a dependent variable and independent variable(s) without the model assumptions of the regression methods. (2) MARS gives us different functions for distinct intervals of independent variables. MARS can not only analyze the effect of independent variables on the dependent variable, but it can also analyze all degrees of the interactions of the independent variables with each other. Moreover, it can show the effect of these interactions on the dependent variable. (3) MARS is a stepwise regression model which can be more easily understood and interpreted than other classification techniques. (4) There is no restriction on the variable type. It may be used categorically or continuously (Garcia Nieto et al., 2017; Lee & Chen, 2005).

Data Analysis

R Studio tool was used for data analysis. There are many packages for machine learning algorithms in R, but the most commonly used packages named as Earth and Caret (Earth package for MARS and Caret package for CART) were used in this research.

First of all, descriptive statistics were given. Secondly, in order to avoid overfitting/underfitting problem, k-fold cross-validation with n-repeat process was run for each algorithm (Khun & Johnson, 2013). In this research, 10-fold with 10-repeat process was used. This process had the following steps:

1. Data divided into 10 equal parts randomly.
2. 9 of 10 parts were used as training samples and the last part was used as a test sample.
3. The process from step 1 to 2 was repeated 10 times and each time the algorithm chose a different portion as the testing data.

After 10-fold cross-validation with 10-repeat process, the most important factors that had a significant effect on science achievement were determined. Furthermore, these factors were ranked by their importance on science achievement. Finally, the results of MARS and CART were compared in terms of model accuracy statistics, which are R^2, Mean Absolute Error (MAE), Mean Square Error (MSE) and Root Mean Square Error (RMSE) to find the best model.

Results of Research

The indexed variables described in Table 1 were used in CART and MARS algorithms. Thus, in general, the higher values in the variables have a positive meaning for the related topic. The descriptive statistics of the students-related variables for Turkey and Singapore are given in Table 2.

Table 2. The comparison of descriptive statistics between Turkey and Singapore.

	Turkey				Singapore			
Variables	$\overline{X}$	SD	Min	Max	$\overline{X}$	SD	Min	Max
pv1scie	433	76	218	708	562	98	228	888
adinst	0.10	0.95	-1.97	2.05	0.41	0.89	-1.97	2.05
anxtest	0.33	1.03	-2.51	2.55	0.57	0.95	-2.51	2.55
belong	-0.40	1.12	-3.13	2.60	-0.22	0.88	-3.13	2.61
cooperate	0.02	1.10	-3.33	2.29	0.33	1.01	-3.33	2.29
cpsvalue	-0.03	0.92	-2.83	2.10	0.26	1.03	-2.83	2.10
cultposs	-0.23	0.87	-1.71	2.46	-0.19	0.98	-1.63	2.56
disclisci	-0.12	0.94	-2.42	1.88	0.19	0.89	-2.42	1.88
emosups	-0.23	1.06	-3.08	1.10	-0.24	0.97	-3.08	1.10
envaware	0.57	1.43	-3.38	3.29	0.43	1.10	-3.38	3.29
envopt	-0.60	1.42	-1.79	3.01	-0.07	1.14	-1.79	3.01
epist	-0.18	1.15	-2.79	2.16	0.24	0.89	-2.79	2.16
escs	-1.40	1.15	-4.65	2.20	0.02	0.90	-4.05	3.50
hedres	-0.54	1.11	-4.37	1.18	0.17	1.01	-4.37	1.18
homepos	-1.38	1.09	-6.71	3.05	-0.11	0.89	-5.43	5.12
ibteach	0.31	1.14	-3.34	3.18	0.00	0.84	-3.34	3.18
ictres	-1.15	0.94	-3.27	3.50	0.20	0.93	-3.27	3.50
instscie	0.39	0.89	-1.93	1.74	0.53	0.80	-1.93	1.74
intbrsci	-0.03	1.01	-2.58	2.73	0.31	0.88	-2.55	2.60
joyscie	0.13	1.14	-2.12	2.16	0.62	0.97	-2.12	2.16
mmins	228	76	0	640	309	142	0	1800
motivat	0.64	0.99	-3.09	1.85	0.43	0.94	-3.09	1.85
perfeed	0.33	0.96	-1.53	2.50	0.32	0.91	-1.53	2.50
scieact	0.68	1.13	-1.76	3.36	0.20	1.08	-1.76	3.36
scieeff	0.36	1.27	-3.76	3.28	0.12	1.09	-3.76	3.28
smins	209	105	0	800	333	167	0	1920
tdteach	-0.06	0.96	-2.45	2.08	0.27	0.93	-2.45	2.08
teachsup	0.19	0.98	-2.72	1.45	0.30	0.87	-2.72	1.45
unfairtchr	10.2	3.9	4.0	24.0	9.9	3.7	5.0	24.0
wealth	-1.45	0.98	-4.93	4.09	-0.18	0.83	-4.77	4.08
autict	n/a	n/a	n/a	n/a	0.20	0.96	-2.50	2.10
compict	n/a	n/a	n/a	n/a	-0.01	0.89	-2.66	1.97
entuse	n/a	n/a	n/a	n/a	-0.10	0.81	-3.71	4.85
homesch	n/a	n/a	n/a	n/a	0.02	0.89	-2.69	3.60
icthome	n/a	n/a	n/a	n/a	7.94	1.93	0.00	11.00

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	Turkey				Singapore			
Variables	$\overline{X}$	SD	Min	Max	$\overline{X}$	SD	Min	Max
ictsch	n/a	n/a	n/a	n/a	6.70	2.13	0.00	10.00
intict	n/a	n/a	n/a	n/a	0.28	0.92	-2.96	2.64
soiaict	n/a	n/a	n/a	n/a	0.15	0.91	-2.14	2.43
usesch	n/a	n/a	n/a	n/a	0.00	0.92	-1.67	3.63

CART algorithm's tree diagram of the Turkey dataset is given in Figure 1.

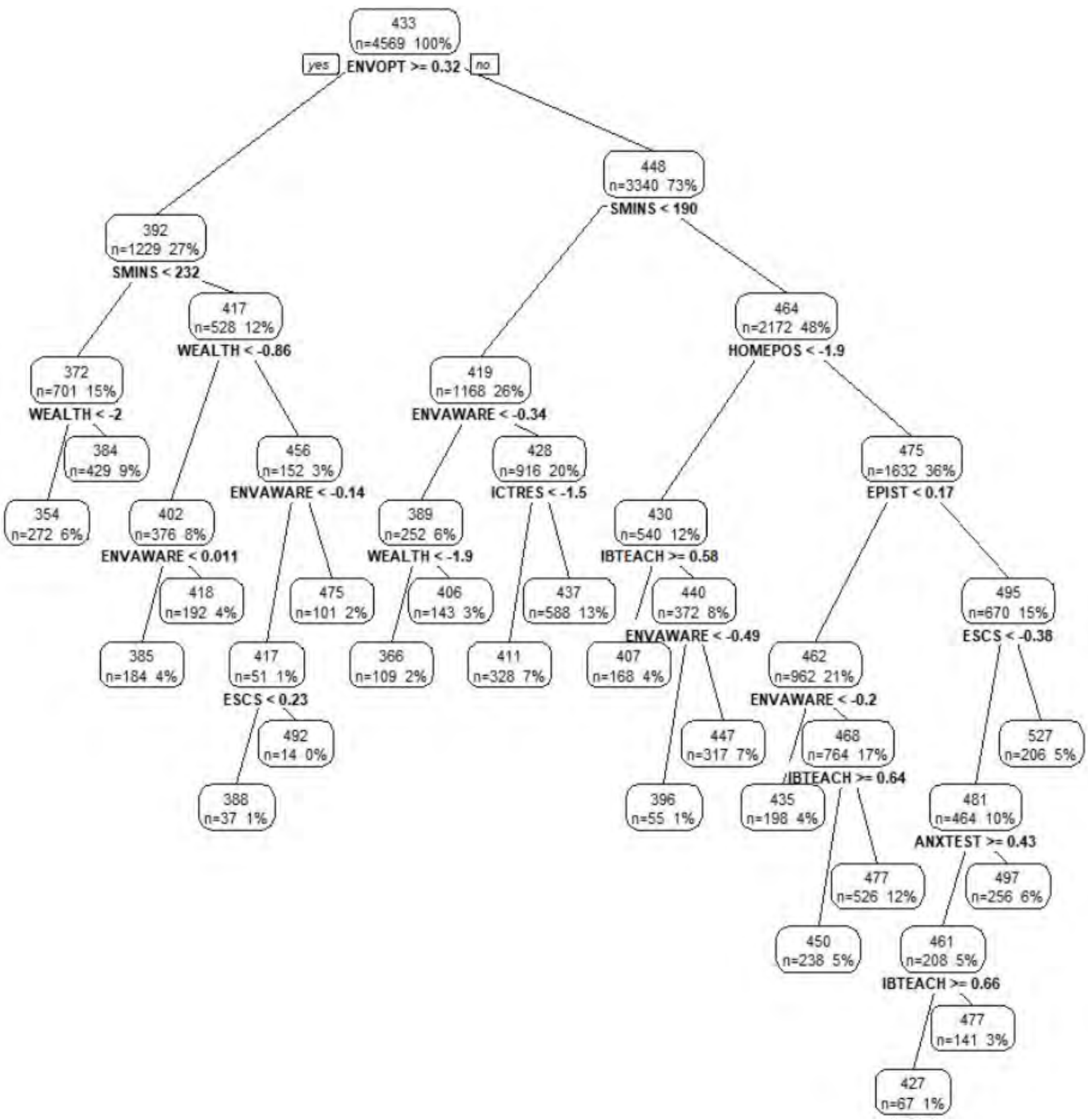

Figure 1. **CART diagram for Turkey dataset (based on min relative error).**

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According to CART diagram, environmental optimism was the most important variable in science achievement. The variables from the most important to the least important for achievement were envopt, smins, homepos, wealth, ictres, envaware, escs, epist, ibteach and anxtest, respectively.

Cut off points of the variables and interaction effects in CART model are shown in Figure 2.

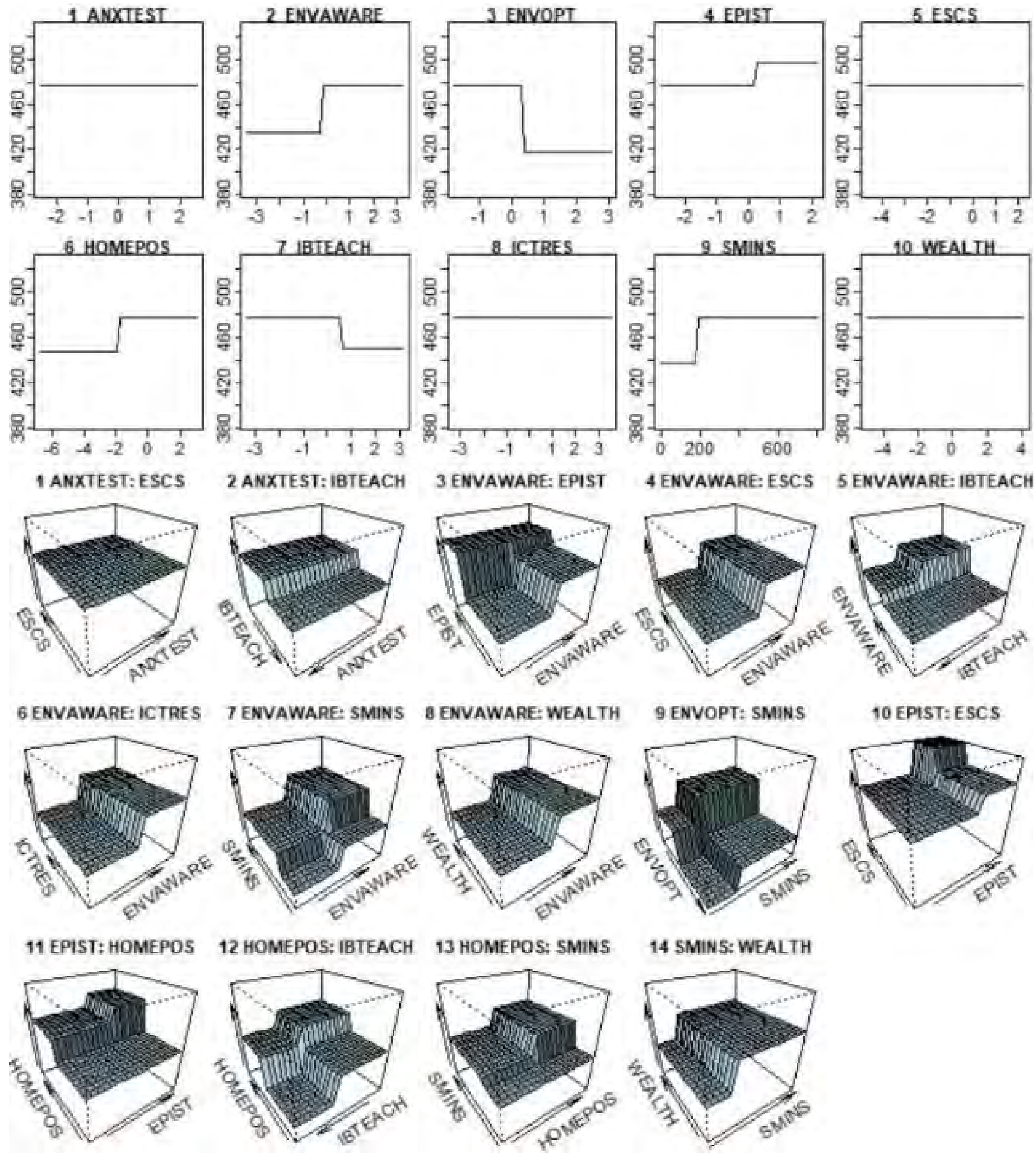

Figure 2. The cutoff points of the variables in the CART model for Turkey dataset.

As a result of CART model for Turkey dataset, R^2, MAE, MSE and RMSE statistics were 0.332, 49.773, 3860.814 and 62.135, respectively.

As seen in Figure 3, MARS algorithm with 2-way interactions was used for Turkey dataset and cut points of variables which had a statistically significant effect on achievement.

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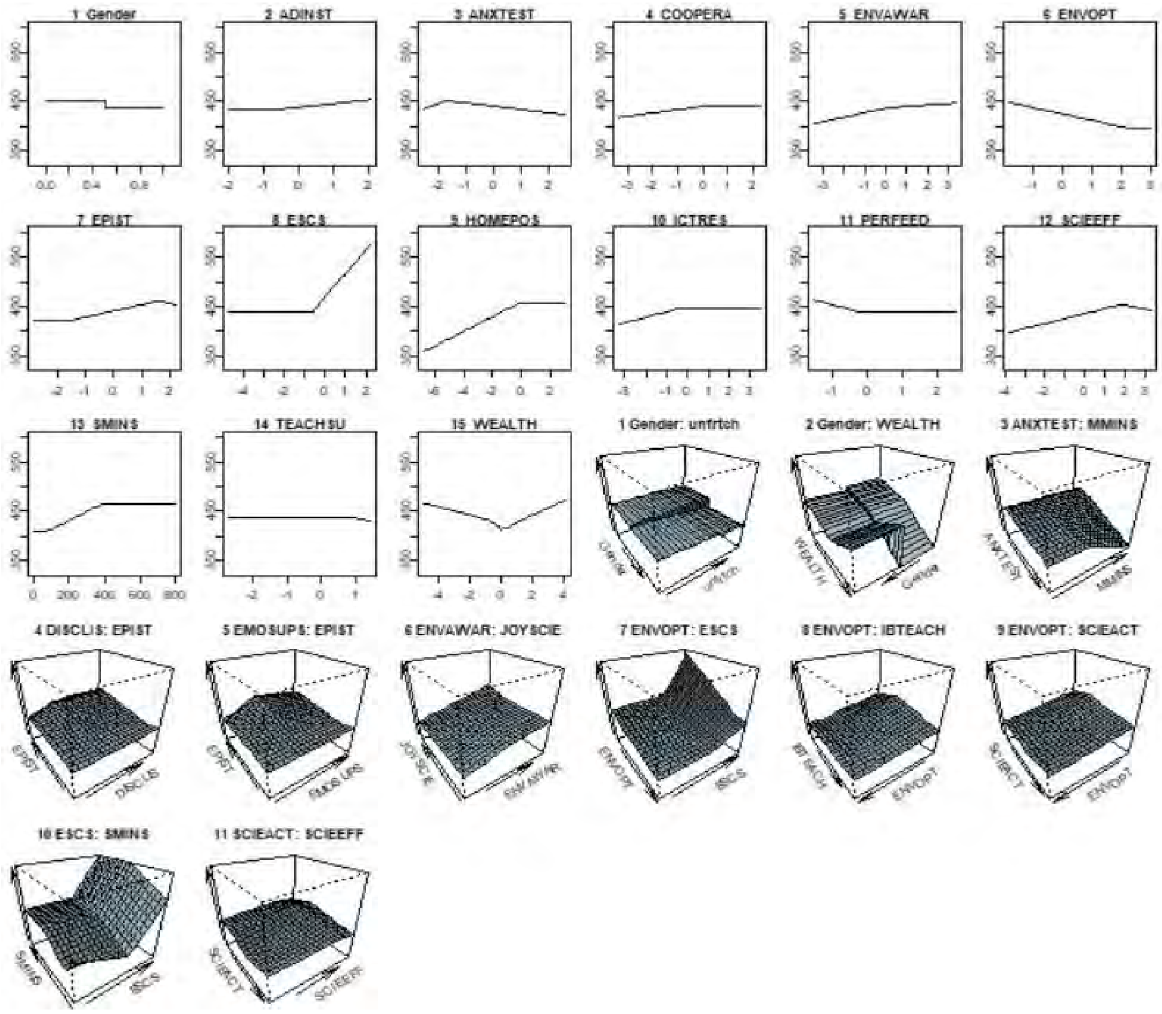

Figure 3. The cutoff points of the variables in the MARS model for Turkey dataset.

37 basis functions were determined for MARS analysis and coefficients of significant variables and interaction effects are given in Table 3.

Table 3. MARS output for Turkey dataset.

Basis Functions	Coefficient	Basis Functions	Coefficient
(Intercept)	467.471	h(-0.7275-wealth)	8.066
gender	-9.336	h(wealth- -0.7275)	-23.794
h(adinst- -0.3816)	7.304	gender * h(unfairteacher-7)	-1.420
h(-1.7251-anxtest)	-21.941	gender * h(wealth-0.0849)	38.563
h(anxtest- -1.7251)	-6.585	h(anxtest- -1.7251) * h(mmins-240)	-0.050
h(0.2085-cooperate)	-6.825	h(-1.0005-disclisci) * h(epist- -1.5276)	-6.952
h(0.1184-envaware)	-9.268	h(-1.3298-emosups) * h(epist- -1.5276)	-9.265
h(envaware-0.1184)	2.907	h(emosups- -1.3298) * h(epist- -1.5276)	-3.066
h(2.2486-envopt)	19.060	h(envaware-0.1184) * h(joyscie-0.5094)	5.032
h(epist- -1.5276)	16.462	h(-1.7476-envopt) * h(escs- -0.6417)	-723.513
h(epist-1.5636)	-24.364	h(envopt- -1.7476) * h(escs- -0.6417)	-7.913
h(escs- -0.6417)	53.250	h(2.2486-envopt) * h(ibteach- -0.8489)	-2.817

Basis Functions	Coefficient	Basis Functions	Coefficient
h(-0.2221-homepos)	-14.896	h(2.2486-envopt) * h(-0.8489-ibteach)	-2.387
h(-0.4459-ictres)	-11.031	h(2.2486-envopt) * h(scieact- -0.0265)	-3.170
h(-0.1713-perfeed)	17.944	h(2.2486-envopt) * h(-0.0265-scieact)	-3.560
h(1.8814-scieeff)	-11.037	h(-0.6417-escs) * h(90-smins)	0.182
h(scieeff-1.8814)	-7.896	h(1.3364-scieact) * h(1.8814-scieeff)	2.730
h(400-smins)	-0.177	h(scieact-1.3364) * h(1.8814-scieeff)	5.039
h(teachsup-0.9209)	-15.016		

Similar to CART algorithm, the variables from the most important to the least important on achievement in MARS analysis were envopt, homepos, smins, epist, envaware, ibteach, anxtest, escs, joyscie, scieact, gender, unfairteacher, scieeff, mmins, perfeed, wealth, cooperate, emosups, adinst, teachsup, disclisci and ictres. As a result of MARS analysis for Turkey dataset, R^2, MAE, MSE and RMSE statistics were 0.417, 46.349, 3365.63 and 58.015, respectively.

In this research, CART and MARS algorithms were used for Singapore dataset to compare the results of two algorithms. CART Tree diagram of Singapore dataset is given in Figure 4.

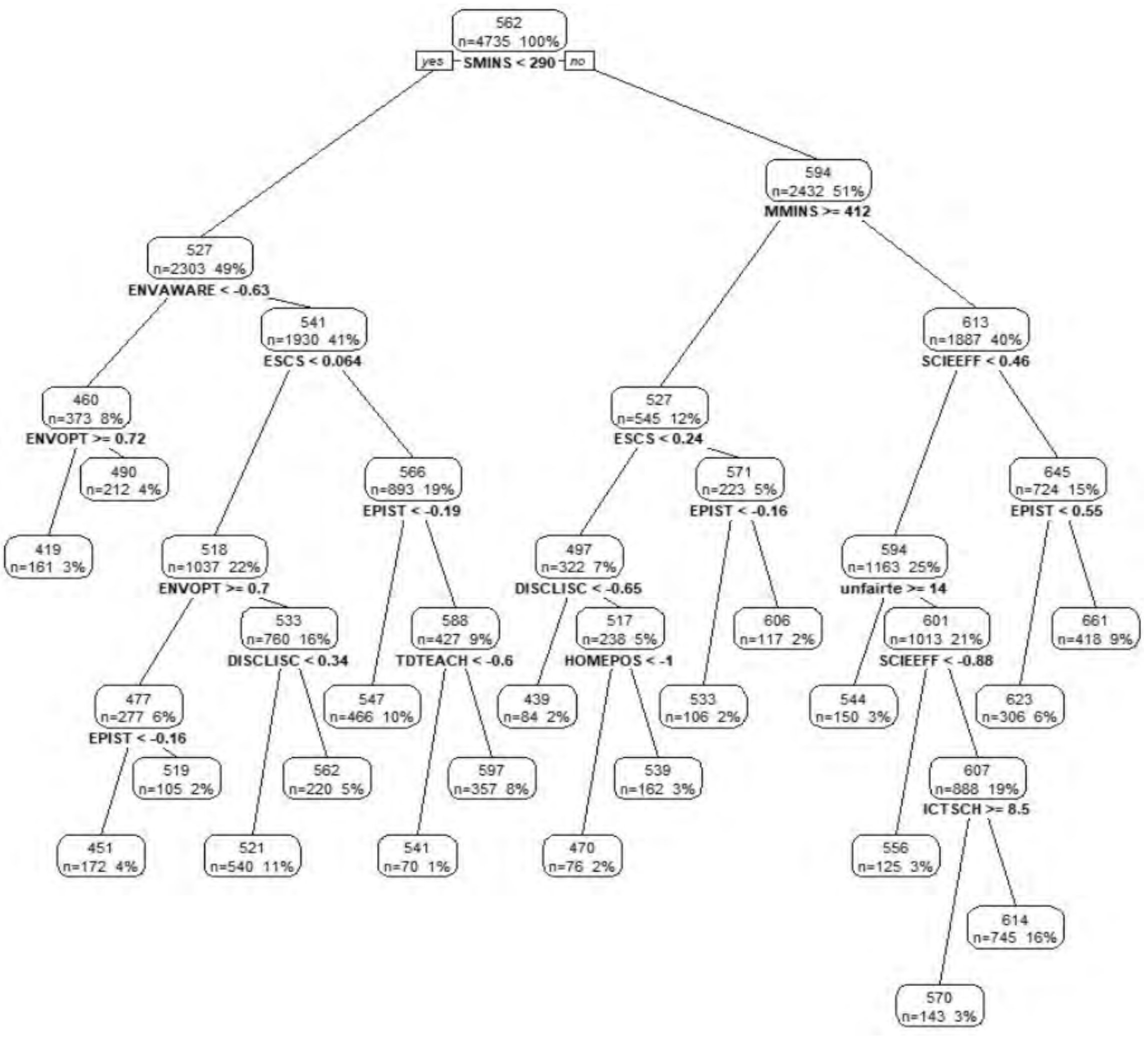

Figure 4. CART diagram for Singapore dataset (based on min relative error).

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Based on Figure 4, learning time (minutes per week) of science subject was the most important variable in science achievement. Variables affecting on achievement (from the most important to the least important) were smins, mmins, envaware, escs, scieeff, epist, homepos, disclisci, envopt, unfairteacher, tdteach and ictsch, respectively.

When cut points of the variables were examined, students whose smins was higher than 290 minutes, the mmins was lower than 412 minutes, the scieeff score higher than 0.46 and the epist score higher than 0.55 had the highest science score with 661. On the other hand, students whose smins was lower than 290 minutes, the enware score was lower than -0.63 and the envopt score was higher than 0.71 had the lowest science score with 419.

As seen in Figure 5, there are cut off points of the variables in CART algorithm.

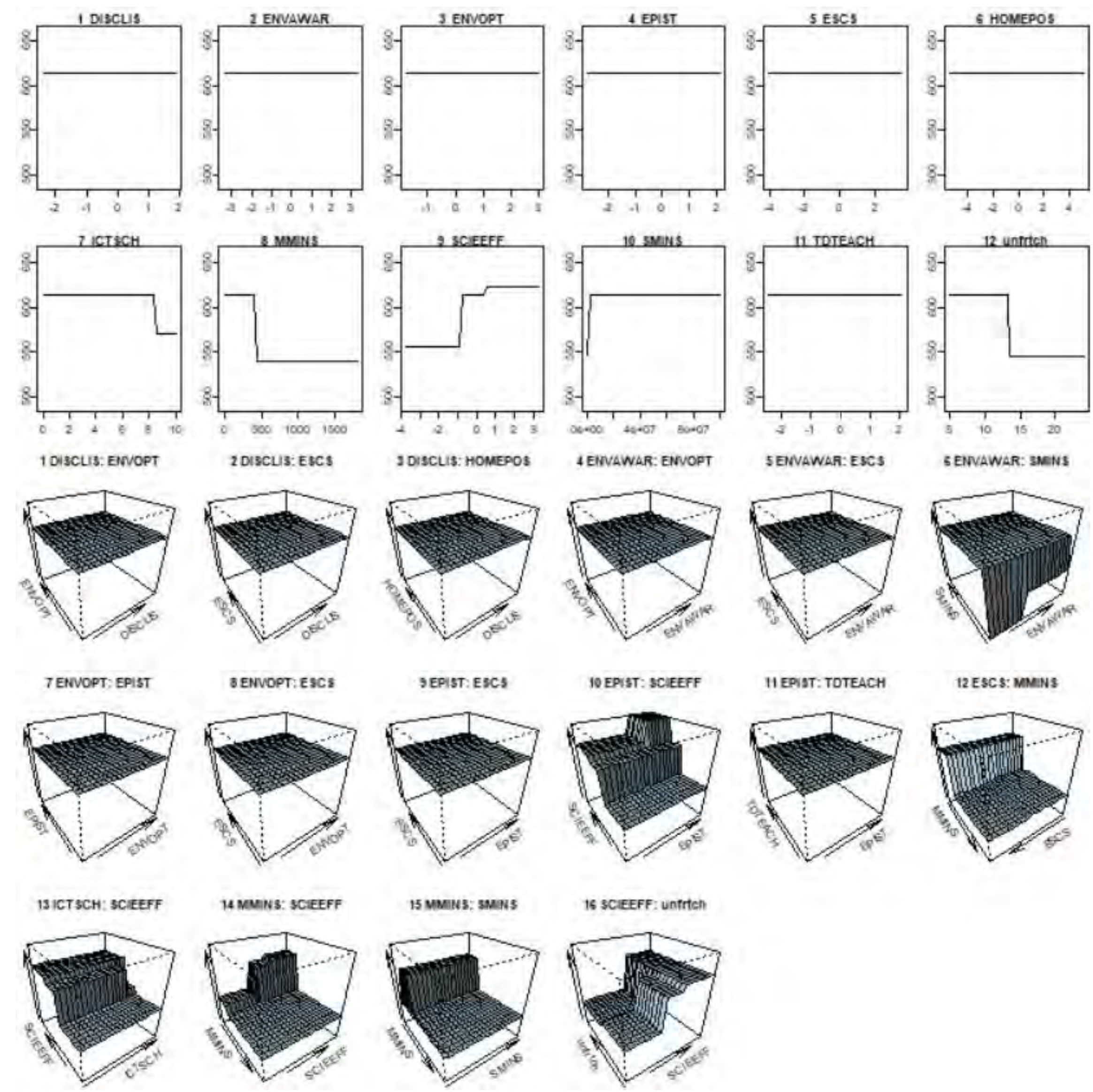

Figure 5. The cutoff points of the variables in the CART model for Singapore dataset.

As a result of CART model for Singapore dataset, R^2, MAE, MSE and RMSE statistics were 0.390, 60.621, 5872.865 and 76.634, respectively.

MARS algorithm with 2-way interactions was used for Singapore dataset and cut off points of variables are shown in Figure 6.

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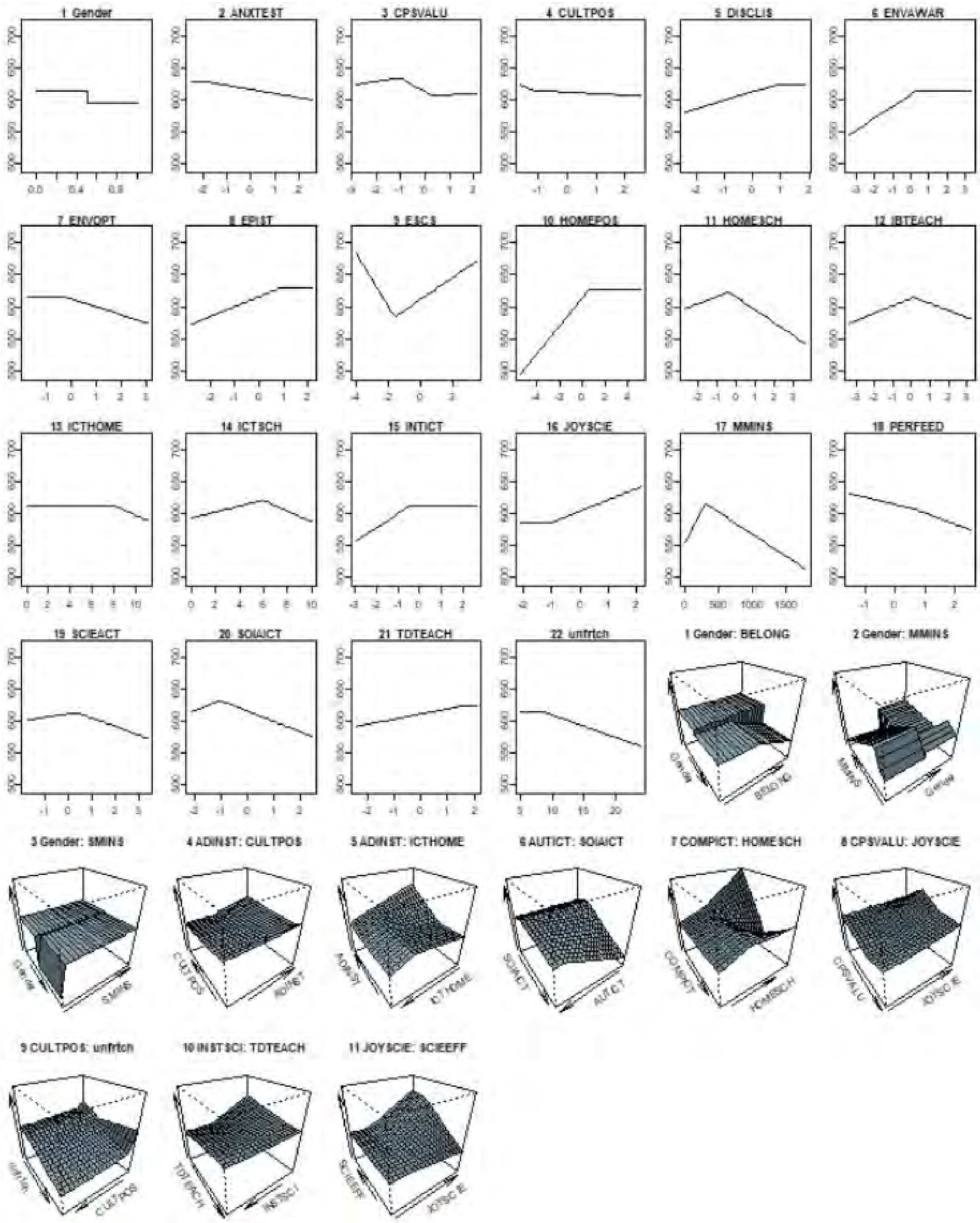

Figure 6. The cutoff points of the variables in the MARS model for the Singapore dataset.

48 functions were determined for MARS analysis and coefficients of significant variables and interaction effects are given in Table 4.

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Table 4. MARS output for Singapore dataset.

Basis Functions	Coefficients	Basis Functions	Coefficients
(Intercept)	664.857	h(mmins-300)	-0.069
gender	-30.874	h(0.6178-perfeed)	11.132
h(anxtest- -1.9346)	-6.490	h(perfeed-0.6178)	-17.399
h(0.3821-cpsvalue)	11.953	h(0.4035-scieact)	-5.511
h(cpsvalue-0.3821)	10.685	h(scieact-0.4035)	-13.441
h(cultposs- -1.1752)	-5.213	h(-0.999-soiaict)	-16.011
h(0.8351-disclisci)	-13.327	h(soiaict- -0.999)	-7.363
h(0.3361-envaware)	-18.450	h(1.4501-tdteach)	-8.063
h(envopt- -0.3192)	-12.635	h(unfairteacher-9)	-3.509
h(0.84-epist)	-15.757	gender * h(belong- -0.5178)	-14.235
h(-1.6073-escs)	40.991	gender * h(mmins-540)	0.097
h(escs- -1.6073)	17.183	gender * h(540-mmins)	0.117
h(0.578-homepos)	-22.209	gender * h(360-smins)	-0.234
h(-0.388-homesch)	-11.277	h(adinst- -0.3816) * h(cultposs- -1.1752)	3.637
h(homesch- -0.388)	-20.172	h(adinst- -0.3816) * h(8-icthome)	3.875
h(0.1368-ibteach)	-11.813	h(1.515-autict) * h(soiaict- -0.999)	-6.368
h(ibteach-0.1368)	-10.854	h(0.0226-compict) * h(homesch- -0.388)	16.333
h(8-icthome)	-3.048	h(compict-0.0226) * h(homesch- -0.388)	9.222
h(icthome-8)	-7.622	h(-1.039-cpsvalue) * h(joyscie- -1.0286)	-11.710
h(6-ictsch)	-4.637	h(cpsvalue- -1.039) * h(joyscie- -1.0286)	-5.259
h(ictsch-6)	-8.416	h(-1.1752-cultposs) * h(unfairteacher-12)	11.652
h(-0.3944-intict)	-21.561	h(-1.1752-cultposs) * h(12-unfairteacher)	5.907
h(joyscie- -1.0286)	31.771	h(0.3708-instscie) * h(1.4501-tdteach)	6.997
h(300-mmins)	-0.206	h(joyscie- -1.0286) * h(1.4886-scieeff)	-6.261

In order to evaluate the performance of the machine learning algorithm in terms of prediction accuracy, the results of the algorithms are summarized in Table 5.

Table 5. The goodness of fit statistics comparison.

Goodness of Fit Criteria	Turkey		Singapore	
	CART	MARS	CART	MARS
R2	0.332	0.417	0.390	0.552
MAE	47.776	46.349	60.621	52.115
MSE	3860.81	3365.63	5872.87	4310.93
RMSE	62.14	58.02	76.63	65.66

The analytic results demonstrated that the MARS algorithm had lower MAE, MSE and RMSE and higher R^2 values than CART algorithm in Turkey and Singapore. The variable importance comparison of the two algorithms is summarized in Table 6.

Table 6. Variable Importance.

Importance	Turkey		Singapore	
	CART	MARS	CART	MARS
1	envopt	envopt	smins	escs
2	smins	homepos	mmins	envaware
3	homepos	smins	envaware	joyscie
4	wealth	epist	escs	ictsch
5	ictres	envaware	scieeff	autict
6	envaware	ibteach	epist	soiaict
7	escs	anxtest	homepos	unfairteacher
8	epist	escs	disclisci	gender
9	ibteach	joyscie	envopt	smins
10	anxtest	scieact	unfairteacher	envopt
11		gender	tdteach	disclisci
12		unfairteacher	ictsch	cpsvalue
13		scieeff		epist
14		mmins		perfeed
15		perfeed		homepos
16		wealth		icthome
17		cooperate		scieeff
18		emosups		mmins
19		adinst		homesch
20		teachsup		belong
21		disclisci		tdteach
22		ictres		anxtest
23				intict
24				instscie
25				compict
26				ibteach
27				scieact
28				cultposs
29				adinst

1: the most important; 29: the less important

In Table 6, it was revealed that the top three most important variables in science achievement were not differentiated in CART and MARS algorithms in the Turkey dataset. However, their ranking was different. Furthermore, according to the results of CART and MARS algorithms, more variables were used in MARS algorithm to explain science achievement.

Similar to the variable importance results of Turkey dataset, more variables were used with MARS algorithm in the Singapore dataset. However, the top three most important variables in science achievement were differentiated in CART and MARS algorithms in Singapore dataset and only the envaware was common.

As a result, MARS algorithm used more variables and produced much more sensitive results than CART algorithm in this dataset. In addition to this, MARS produced higher R^2 and lower MAE, MSE and RMSE values than CART algorithm. Thus, it could be said that MARS algorithm outperformed CART algorithm in this research.

Discussion

During the past decades, students' factors affecting academic achievement have become very common and important for the educational system. Research institutions and government agencies are evaluating this

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topic to develop actionable decisions on students' achievement. In this research, when the variable importance was examined, it was revealed that environmental optimism, home possessions and science learning time (minutes per week) were the most important factors that needed to be improved for Turkish students to increase students' science achievement. This result was parallel to the results obtained in the researches in the literature (Hoy, Tarter, & Hoy, 2006; Littledyke, 2008; Yang, 2010; Singh, Granville, & Dika, 2010).

According to the average score of environmental optimism and basis function result of MARS, it is clear that Turkish students do not have enough knowledge about its sub-criteria: air pollution, extinction of plants and animals, clearing of forests for other land use, water shortages, nuclear waste, the increase of greenhouse gases in the atmosphere and the use of genetically modified organisms. Moreover, their future expectation of these criteria is not optimistic. Also, this variable should be higher than 2.2486 to increase science achievement for Turkish students. The impact of environmental optimism on Singaporean students' science achievement was not as important as the impact on Turkish students' science achievement. Although Turkey's government began steering up its environmental awareness in the early 1980s, a major policy was included in the country's 10th development plan in 2014. These policies are increasing the development of Turkey's renewable energy, prevention and adaptation to climate change, conservation of biodiversity, soil erosion control, reforestation and fighting desertification and reforestation (Smith, 2015). However, it is clearly concluded that the importance of these programs is not realized by the government. Also, Turkey is 37th rank out of 38 countries in the environment category of OECD's better life index. This result corresponds to the findings of the OECD's report (OECD, 2017). When Singapore environmental policy is examined, it is seen that its environmental awareness started in the early 1970s. In the research of Hays (2008), it was emphasized that the Singapore government has been aware of the requirements for environmental protection since the 1970s. For this reason, Minister's Offices were established and these offices carried out many programs about cleaning up rivers and streams, moving animals to resettlement areas and controlling discharges from small industries to handle environmental issues. Because of the early implementation of environmental action plans in Singapore, it can be inferred that the average environmental optimization score of Singapore is higher than Turkey. Thus, we are expecting that environmental awareness and optimism are going to increase in the near future after the action plans that are taken by Turkish government.

In this research, another important factor that affects Turkish students' science achievement was home possessions. Home possessions variable consists of 20 different items: a desk to study at, a room of their own, a quiet place to study, a computer they can use for school work, educational software, a link to the Internet, classic literature, books of poetry, books to help with your school work, a dictionary, books on art, music or design, televisions, cars, rooms with a bath or shower, cell phones with internet access, computers, tablet computers, e-book readers, musical instruments and the number of books. Average home possessions score was -1.38 for Turkey and -0.11 for Singapore. Based on MARS results, this variable should be higher than -0.2221 for better science achievement score. Similar to the researches in the literature, home possessions, which were highly correlated to socio-economic status (Turmo, 2004; Marks, Cresswell, & Ainley, 2006), had a significant effect on students' science achievement in this research. Gallup conducted a survey from November 11th to December 25th in 2013 in order to understand media usage behavior in Turkey (Gallup, 2013). 2,020 people were attended in the survey and 99% of them had a television, 72% of them had a working computer and 68% of them had an internet connection and 78% of the population had a cell phone. The importance of home possessions on science achievement for Singaporean students was relatively lower than Turkish students. On the other hand, 98% of people had a television, 83% of people had a working computer, 78% of them had an internet access and 97% of people had a cell phone (Department of Statistics Singapore, 2018). In addition to this, gross domestic product per capita was 55,235$ in Singapore while 14,933$ in Turkey as of December 2017 (Trading Economics, 2018). It is obvious that socioeconomic cultural status of Singapore is better than Turkey. Thus, Turkish government should create action plans to increase health and decency standard of living.

The results of this research corresponded to the findings of other studies in the literature (Chandler & Swartzentruber, 2011; Sha, Schunn, & Bathgate, 2015). Science learning time had a significant effect on Turkish students' science achievements. Science learning time was 209 minutes on average for Turkey and 333 minutes for Singapore in this research. According to the MARS results, an average of science learning time should be over 400 minutes per week for being more effective. This means that the current curriculum should be updated immediately. Science learning time should be increased to (at least) 333 minutes per week and then it should be increased to 400 minutes in order to reach a high level of science success.

After evaluating the important factors affecting on Turkish students' science achievement, it could be found that family wealth, adaption of instruction, environmental awareness, epistemological beliefs and internet and computer technology (ICT) resources were important factors that had a significant impact on students' science achievement (Geske & Kangro, 2002; Özdem, Çavaş, Çavaş, Çakıroğlu, & Ertepınar, 2010; Záhorec, Hašková, Munk, & Bílek, 2013; Henno & Reiska, 2013; Rannikmäe, 2016). In this research, these variables should be higher than 0.7275, 0.3816, 0.1184, 1.5276 and 0.4459, respectively in order to reach a high level of science achievement. When the results of MARS for Singapore examined, it was revealed that index of economic, social and cultural status, environmental awareness, enjoyment of science, ICT available at school index and students' perceived autonomy related to ICT use variables should be higher than 1.6073, 0.3361, 1.0286, 6.000 and 1.515, respectively in order to reach high level of science achievement.

According to the research findings, MARS was outperformed CART in terms of predicting students' science achievement. The performance analysis indicated that MARS had the highest coefficient of determination with the value of 42% in Turkey and 55% in Singapore.

Conclusions

In overview, science achievement is critical for developing science literacy which is explored by PISA surveys. It is assessed the students' science knowledge as well as what they can do and how they can apply scientific knowledge in real life. According to the results of PISA 2015, it has been concluded that science achievement of Turkish students is lower than the OECD average. Therefore, it is necessary to explore how to develop scientific literacy.

It was determined that environmental optimism had a positive significant effect on students' science achievement. The government should be able to support people with high levels of knowledge about environmental awareness to provide training or workshop. In addition, these people can be invited as a speaker in high schools' or companies' training programs in order to increase environmental awareness. Providing in-service training to teachers and educators or preparing a public service announcement could be another way to promote environmental knowledge.

Home possessions were the second important factor that had a significantly positive effect on students' achievement. When the sub-criteria of home possessions are considered, it can be said that it is really hard to increase students' home possessions score in a short time. However, parents should provide their children with a desk to study at and a quiet place to study. Also, it is critical for developing students' science achievement that students have a computer with an internet access in both their home and school. Since providing a computer and an internet access are a budgeting issue for parents, the government should support schools to set up at least one computer laboratory with an internet access.

It was emphasized that science learning time was one of the other factors affecting students' science achievement. Science learning time per week was 209 minutes in Turkey, which was below PISA overall average. In the light of this research, it is recommended that science learning time per week should be increased and the curriculum should be enriched. For that reason, educational policymakers and the government should work on how to make an effective educational plan.

Although this research should give a reference in this field for future research, there are some limitations in this research. Firstly, in order to explain the students' science achievement, it can be included in the analysis not only student variables but also teacher-related and school-related variables which are obtained by PISA survey. Secondly, Singapore is the most successful country of PISA 2015 in terms of science achievement, so PISA data is analyzed to make a comparison between Turkey and Singapore in this research. Other countries participating in PISA survey may also be analyzed to compare students' achievement. Thirdly, there are so many machine learning techniques for solving different problems. It is used MARS and CART algorithms in this research. In order to measure prediction and classification performance, different machine learning techniques can be tried in future research.

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References

Breiman, L., Friedman, J. H., Olshen, R. A., & Stone C.J. (1984). *Classification and regression trees.* Monterey: Wadsworth and Brooks/Cole.

Carnoy, M., Khavenson, T., & Ivanova, A. (2013). Using TIMSS and PISA results to inform educational policy: A study of Russia and its neighbours. *Compare: A Journal of Comparative and International Education*, *45* (2), 248-271.

Chandler, K., & Swartzentruber, M. (2011). A correlational study of nature awareness and science achievement (M.A Thesis). Retrieved from https://files.eric.ed.gov/fulltext/ED520105.pdf.

Cortez, P., & Silva, A. (2008). Using data mining to predict secondary school student performance. In A. Brito & J. Teixeria (Eds.), *Proceedings of 5th Annual Future Business Technology Conference* (pp.5-12). Porto, Portugal: EUROSIS.

Department of Statistics Singapore (2018). *Singapore in Figures 2018*. Singapore: Department of Statistics.

Friedman, J. H. (1991). Multivariate adaptive regression splines (with discussion). *The Annals of Statistics*, *19* (1), 1-141.

Gallup, (2013). *Contemporary Media Usage in Turkey*. Retrieved from Broadcasting Board of Governors: https://www.bbg.gov/wp-content/media/2014/07/Turkey-research-brief.pdf.

Garcia Nieto, P. J., Garcia-Gonzalo, E., Alvarez Anton, J. C., Gonzalez Suarez, V. M., Mayo Bayon, R., & Mateos Martin, F. (2017). A comparison of several machine learning techniques for the centerline segregation prediction in continuous cast steel slabs and evaluation of its performance. *Journal of Computational and Applied Mathematics*, *330* (1), 1-19.

Geske, A., & Kangro, A. (2002). Evaluation of Latvia's science education in the IEA TIMSS and OECD PISA framework. *Journal of Baltic Science Education*, *1* (2), 59-66.

Hay, J. (2018, August 1). *Singapore - History, Nature and Religion*. Retrieved from http://factsanddetails.com/southeast-asia/Singapore/sub5_7a/entry-3795.html

Henno, I., & Reiska, P. (2013). Impact of the socio-cultural context on student science performance and attitudes: The case of Estonia. *Journal of Baltic Science Education, 12* (4), 465-481.

Hoy, W. K., Tarter, C. J., & Hoy, A. W. (2006). Academic optimism of schools: A force for student achievement. *American Educational Research Journal*, *43* (3), 425-446.

Kabakchieva, D. (2013). Predicting student performance by using data mining methods for classification. *Cybernetics and Information Technologies*, *13* (1), 61-72.

Khun, M., & Johnson, K. (2013). *Applied Predictive Modeling*. New York, NY: Springer.

Lee, T.-S., & Chen, I.-F. (2005). A two-stage hybrid credit scoring model using artificial neural networks and multivariate adaptive regression splines. *Expert Systems with Applications*, *28*, 743-752.

Littledyke, M. (2008). Science education for environmental awareness: approaches to integrating cognitive and affective domains. *Environmental Education Research*, *14* (1), 1-17.

Marks, G. N., Cresswell, J., & Ainley, J. (2006). Explaining socioeconomic inequalities in student achievement: The role of home and school factors. *Educational Research and Evaluation*, *12* (2), 105-128.

Martinez A., F., & Chaparro Caso López, A.A. (2017). Data mining techniques in detecting factors linked to academic achievement. *School Effectiveness and School Improvement*, *28* (1), 39-55.

Milli Eğitim Bakanlığı (MEB). (2016). *PISA 2015 National Report*. MEB: Ankara.

Organisation for Economic Co-operation and Development (OECD). (2017). *How's Life? 2017: Measuring Well-being*. Paris: OECD Publishing.

Organisation for Economic Co-operation and Development (OECD). (2018). *PISA 2015 Results in Focus*. Paris: OECD Publishing.

Trading Economics. (2018, August 1). *GDP per Capita*. Retrieved from https://tradingeconomics.com/country-list/gdp-per-capita

Özdem, Y., Çavaş, P., Çavaş, B., Çakıroğlu, J., & Ertepınar, H. (2010). An investigation of elementary students' scientific literacy levels. *Journal of Baltic Science Education, 9* (1), 6-19.

Rannikmäe, M. (2016). Some crucial areas in science education research corresponding to the needs of the contemporary society. *Journal of Baltic Science Education, 15* (1), 4-6.

Rutkowski, D., Rutkowski, L., Wild, J., & Burroughs, N. (2017). Poverty and educational achievement in the US: A less-biased estimate using PISA 2012 data. *Journal of Children and Poverty*, *24* (1), 1-21.

R Studio. (2017, November 1). *Products Page: R Studio*. Retrieved from http://www.rstudio.org/

Sebastian, J., Moon, J., & Cunningham, M. (2012). The relationship of school-based parental involvement with student achievement: A comparison of principal and parent survey reports from PISA 2012. *Educational Studies*, *43* (2), 123-146.

Sha, L., Schunn, C., & Bathgate, M. (2015). Measuring choice to participate in optional science learning experiences during early adolescence. *Journal of Research in Science Teaching*, *52*, 686-709.

Shariri, A. M., Husain, W., & Rashid, N. A. (2015). A review on predicting student's performance using data mining techniques. *Procedia Computer Science*, *72*, 414-422.

Sheldrake, R., Mujtaba, T., & Reiss, M. J. (2017). Science teaching and students' attitudes and aspirations: The importance of conveying the applications and relevance of science. *International Journal of Educational Research*, *85*, 167-183.

Singh, K., Granville, M., & Dika, S. (2010). Mathematics and science achievement: Effects of motivation, interest and academic engagement. *The Journal of Educational Research, 95* (6), 323-332.

Smith, B. (2018, August 1). *Turkey Environmental Issues, Policies and Clean Technology*. Retrieved from https://www.azocleantech.com/article.aspx?ArticleID=571

Turmo, A. (2004). Scientific literacy and socio-economic background among 15 year-olds: A Nordic perspective. *Scandinavian Journal of Educational Research, 48* (3), 287-305.

Türe, M., Tokatlı, F., & Kurt, İ. (2009). Using Kaplan-Meier analysis together with decision tree methods (C&RT, CHAID, QUEST, C4.5 and ID3) in determining recurrence-free survival of breast cancer patients. *Expert Systems with Applications*, *36*, 2017-2026.

Von Davier, A. A., Hao, J., Liu, L., & Kyllonen, P. (2017). Interdisciplinary research agenda in support of assessment of collaborative problem solving: Lessons learned from developing a Collaborative Science Assessment Prototype. *Computers in Human Behavior*, *76*, 631-640.

Yang, Y. (2010). Dimensions of Socio-economic Status and their Relationship to Mathematics and Science Achievement at Individual and Collective Levels. *Scandinavian Journal of Educational Research, 47* (1), 21-41.

Záhorec, J., Hašková, A. M., & Bílek, M. (2013). Results of PISA and Evaluation of Computer Science Education. *Journal of Baltic Science Education, 12* (2), 234-248.

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