

# DETERMINATION OF THE FACTORS AFFECTING STUDENTS' SCIENCE ACHIEVEMENT LEVEL IN TURKEY AND SINGAPORE: AN APPLICATION OF QUANTILE REGRESSION MIXTURE MODEL

Serpil Kiliç Depren

## Introduction

In any society, education plays a critical role because it determines the perspectives of individuals' life. Academic performance is highly correlated with the individuals' future career and occupational choices. To assess academic performance over time, there are studies such as Programme for International Student Assessment (PISA) organized by the Organization Economic for Co-Operation and Development (OECD), Trends in International Mathematics and Science Study (TIMSS) and Progress in International Reading Literacy Study (PIRLS) organized by International Association for the Evaluation of Educational Achievement (IEA). More specifically, science achievement is about understanding and applying the fundamental knowledge of science, drawing conclusions based on data and evidence and developing the significance of science and technology in daily lives (OECD, 2017).

In the literature, empirical research have been made to specify the underlying factors of students' achievement (Contini, Di Tommaso, & Mendolia, 2017; Sheldrake, Mujtaba, & Reiss, 2017; Kılıç Depren, Aşkın, & Öz, 2017; Kılıç Depren, 2018). Zhang, Khan, and Tahirsylaj (2015) have used regression methods to measure the factors affecting students' performance using the dataset of PISA 2009 participating countries. The research of Delprato and Chudgar (2018) has found out the systemic school factors on the private-public performance gap using the Teaching and Learning International Survey (TALIS)-PISA dataset in three countries. Based on a multilevel model, Giambona and Porcu (2018) have identified the most important factor on students' achievement was school size.

In this research, it was assumed that the students' science achievement scores were reflecting a mixture distribution that is a sample of students representing various backgrounds, with some or all backgrounds associated with different distributions and mean scores. Thus, Quantile Regression Mixture Model (QRMIX), which is a unique approach in the education literature, was used to determine the factors affecting students' science achievement in Turkey and Singapore.



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**Abstract.** *In the last decade, the usage of advanced statistical models is growing rapidly in many different disciplines. However, the Quantile Regression Mixture Model (QRMIX), which is a developed approach of the Finite Mixture Model (FMM), is an applicable new method in the educational literature. The aim of the proposed study was to determine factors affecting students' science achievement using the QRMIX approach. To reach this aim, data of the Programme for International Student Assessment (PISA) survey, which has been conducted by the Organization Economic for Co-Operation and Development (OECD) every 3 years, was used. Dataset used in the research is composed of 6,115 students from Singapore, which is the top-performer country among the participant countries, and 5,895 students from Turkey. The results showed that the factors affecting students' science achievement and its importance on the achievement differentiated according to the achievement levels of the students. In conclusion, it was revealed that Turkish students with the lowest science achievement level should be supported with home possessions, perceived feedback, and environmental awareness and Singaporean students with the lowest achievement level should be supported with perceived feedback, enjoyment of science, and epistemological beliefs.*

**Keywords:** *finite mixture models, Programme for International Student Assessment, quantile regression mixture models, science performance.*

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### *Research Problem*

Students' science achievement as measured by scores in PISA 2015 survey shows that Turkey's score (426) was far below the OECD average score (493). Although Turkish government has made a lot of improvements in the educational system during the past decades, the reason why Turkish students received such a low score in science achievement is that educational reforms done by Turkish Government are too general and cannot be thereby implemented for all students at the same time (Oyvatt & Tekgüç, 2019). Both the education systems of Turkey and Singapore are also different in culture, school curriculum, and the quality of teachers. On the other hand, students can be trained according to their technical (such as problem solving, understanding complex problems, etc.) and social (such as mentoring, role modelling skills, awareness of racism and sexism) capabilities in Singapore. Thus, the Singapore education system is able to provide a customized curriculum for different groups of students in a school. In contrary to Singapore, all students have the same curriculum in Turkey. That's why it is hard to improve Turkish students' technical and social capabilities based on their awareness and skills.

In addition to being one of Asia's developed countries, Singapore has achieved remarkable success in education in PISA 2015. Moreover, the amount spent per student as a share of per capita gross domestic product (GDP) is relatively lower than all participating countries. Singapore's educational policy can be taken as a reference point for Turkey that cannot solve the education problem. In addition, it was examined whether the factors affecting students' science achievement are differentiated in Turkey and Singapore. As a result of the analysis, students' skills in applying theoretical knowledge to real-life problems can be improved.

### *Research Focus*

This research examined the factors affecting both Turkish and Singaporean students' science achievement with the following research question:

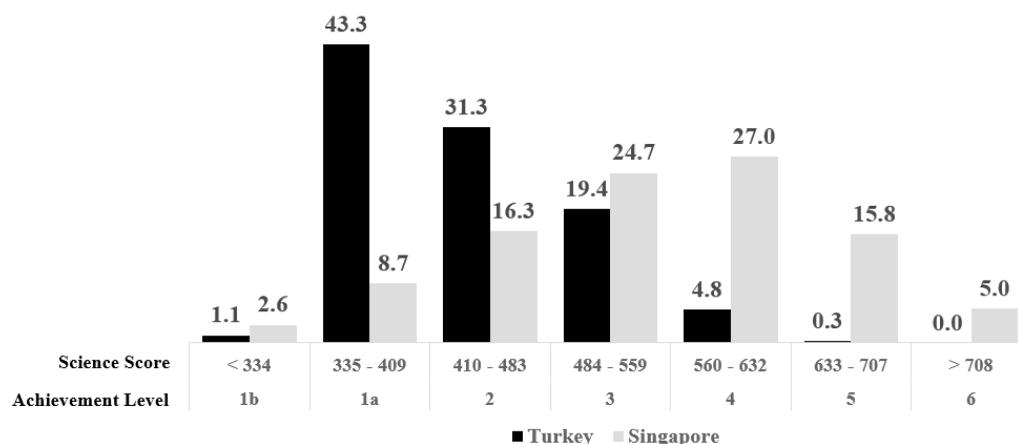
1. Do the factors that affect students' science achievement differs according to their achievement level? If so, what are the thresholds of these achievement levels?
2. What is the main difference between Turkey and Singapore in terms of science achievement?
3. What are the precautions to improve science achievement level of Turkey when Singapore, which is the best-performer country, is taken as a reference point?

## **Research Methodology**

### *General Background*

Since the year 2000, PISA has been held by OECD to compare students' performance among participating countries. PISA survey emphasizes that the tests comprise directly related to students' or schools' characteristics. Besides, these tests are measured by 15-year-old students' knowledge of mathematics, science, and reading every three years. Since science achievement was evaluated by PISA 2015, educational-demographic background factors of the students and tests were used to determine the factors affecting performance in this study. Science achievement was divided into seven levels (higher the better score). Table 1 obtains from the relevant tables in the PISA 2015 report (OECD, 2017) for the science achievement levels of Turkey and Singapore.



**Figure 1***The percentages of the seven science achievement levels in Turkey and Singapore*

From the technical report of the PISA 2015, below level 2 (1a and 1b) is defined as the lower proficiency level. 44% of Turkish students and 11% of Singaporean students are at a lower proficiency level. Level 2 is defined as the basic proficiency and above level 4 is defined as the upper proficiency level. Almost none of the Turkish students and 21% of Singaporean students are at the upper proficiency level (OECD, 2017).

### Sample

The two-stage sampling procedure was used in all PISA surveys. According to the procedure, the first stage was to select the schools, and the second stage was to select the students. In the first stage, systematic probability proportional to size (PPS) sampling procedure was applied for selecting schools to be participated in the survey (OECD, 2017). In the second stage, all PISA-eligible students were listed, and students were randomly selected. If there were fewer than the number of target cluster size-eligible students, all students were selected.

PISA survey, which is conducted by OECD in every 3 years, was implemented in 72 countries of which 35 are OECD countries. In 2015 dataset, there are 5,895 students from Turkey and 6,115 students from Singapore in 2015 (OECD, 2017). Excluding the missing values, 4,177 Turkish students and 4,655 Singaporean students were used in this research. Demographic (gender), socio-economic factors (home possessions, economic, social and cultural status) and other social and school and test environment-related questions (environmental awareness and environmental optimization) were captured by the survey data.

### Instrument and Procedures

The finite mixture model (FMM) provides an interpretable and flexible approach to model heterogeneity of discrete and continuous covariate effects across the distribution of responses (McLachlan & Peel, 2000). In particular, FMM is a powerful technique for explaining asymmetric and non-normal datasets, reducing the dimensionality of data, and dealing with inter-cluster and intra-cluster variations. Unlike average population estimates from standard regression models, FMM partitions data into clusters of finite sub-populations for unobserved heterogeneity. This is substantially more excellent informative and more robust to response variable outliers than Ordinary Least Squares (OLS) for inference (Eide & Showalter, 1998; Levin, 2001). FMM, both fixed and varying weight parameter models, assume a linear relationship of the probability distributions, generally defined components (Park, Lord, & Wu, 2016; Zhu & Melnykov, 2018). With this feature, FMM has been used in many different areas before; the effect of job loss on drinking (Deb, Gallo, Ayyagari, Fletcher, & Sindelar, 2011), the analysis of medical data (Schlattmann, 2009), flow cytometry data (Pyne et al., 2009) and vehicle crash data (Park & Lord, 2009).



The probability density function of  $Y_j$  can be written as follows:

$$f(y|x, \psi) = \sum_{i=1}^N \pi_i f_i(y|x, \theta_i) \quad (1)$$

where  $f_i(y|x, \theta_i)$  are conditional densities,  $\pi_i$  are mixing proportions or weights such that  $\pi_i \geq 0$  and  $\sum_{i=1}^N \pi_i = 1$ ,  $x$  is a vector of independent variables with the specific parameter vector  $\theta_i$  and  $\psi = (\pi_1, \dots, \pi_N, \theta_1, \dots, \theta_N)$  denote the vector of all unknown parameters (McLachlan & Peel, 2000).

In order to estimate the mixtures, a quantile regression (QR) based FMM called QRMIX is used (Emir et al., 2019). This method uses the quantile regression (Koenker, 2005) to find the quantiles that correspond to the components of a mixture distribution and uses a weighted linear combination of these QR functions to obtain an estimate for the whole sample. It is more robust than the likelihood-based FMM. There is an R package in CRAN (R Core Team, 2018) called *qrmix*. to select a group of quantiles that supply for the optimum criteria in terms of goodness of fit statistics.

As a general methodological rule, the correlation between independent variables is questioned for both Turkish and Singapore datasets. While exploring the data, it was noted that there are multi-collinearity problems among the predictors both in Turkish and Singapore datasets. Thus, the Penalized Regression using LASSO (Tibshirani, 1996) was applied. Then, descriptive statistics were presented for the variables selected after the LASSO Regression (Table 2). Finally, different subgroups were defined using QRMIX based on the science achievement of the students. As a result of LASSO Regression, Home Educational Resources, Teacher Support in a Science Classes of Students Choice, Sense of Belonging to School, Personality: Test Anxiety, Home possessions, ICT Resources, Inquiry-based science teaching and learning practices, Teacher-directed science instruction, Environmental Awareness, Environmental optimism, Enjoyment of science, Science self-efficacy, Epistemological beliefs, Index science activities, Collaboration and teamwork dispositions: Enjoy cooperation, Perceived Feedback, Adaption of instruction and Teacher Fairness were excluded from the Turkish dataset because of the multicollinearity problem. Cultural possession, Student Attitudes, Preferences, and Self-related beliefs: Achieving Motivation, Index Highest Parental Education in Years of Schooling, Teacher Support in a Science Classes of Students Choice and Total Learning time (minutes per week) were excluded from the Singapore dataset.

### Data Analysis

PISA 2015 dataset was analyzed using the R Studio tool. There are many packages for data pre-processing and interpreting in R, but in this research, *dplyr* and *qrmix* libraries were used.

Data analysis process had the following steps:

1. The correlation between variables and descriptive statistics (such as mean, standard deviation, min, max, etc.) were calculated.
2. In order to avoid multicollinearity problem, Least Absolute Shrinkage and Selection Operator (LASSO) Regression, which is a shrinkage and variable selection method for linear regression models, was applied to reduce the number of highly correlated variables in order to reach a robust model. The aim of the analysis is to obtain the subset of dependent variables that minimizes prediction error for a dependent variable (Tibshirani, 1996).
3. After the LASSO Regression process, students clustered into sub-groups based on their responses and the most important factors that had a significant effect on science achievement for all subgroups were determined simultaneously using the QRMIX procedure.
4. The results of QRMIX were analyzed for each sub-group and evaluated to provide action plans.

### Research Results

Descriptive statistics for both Turkish and Singaporean students in PISA 2015 are given in Table 1. According to Table 1, there were only three variables that Turkey outperformed Singapore in terms of mean scores. On the other hand, the mean score of Index of economic, social and cultural status, Home possessions and ICT resources in Singapore were significantly higher than Turkey.



**Table 1***Descriptive statistics for both Turkish and Singaporean students from PISA 2015*

Variable Names (Codes in PISA dataset)	Turkey		Singapore		Standard Mean Difference
	Mean	SD	Mean	SD	
Science Achievement Score (PV1SCIE)	426.03	76.85	546.38	104.54	1.21
ICT Resources (ICTRES)	-1.15	0.94	0.14	0.95	1.36
Index of economic, social and cultural status (ESCS)	-1.40	1.16	-0.04	0.92	1.31
Home possessions (HOMEPOS)	-1.39	1.10	-0.17	0.92	1.21
Science Learning time (SMINS)	206.50	99.20	323.80	172.50	0.82
Environmental optimism (ENVOPT)	-0.61	1.42	-0.04	1.18	0.44
Enjoyment of science (JOYSCIE)	0.14	1.14	0.57	1.00	0.40
Epistemological beliefs (EPIST)	-0.16	1.15	0.20	0.91	0.35
Teacher-directed science instruction (TDTEACH)	-0.06	0.96	0.26	0.95	0.34
Disciplinary climate in science classes (DISCLISCI)	-0.11	0.93	0.18	0.90	0.32
Adaption of instruction (ADINST)	0.11	0.95	0.40	0.90	0.31
Personality: Test Anxiety (ANXTEST)	0.32	1.04	0.59	0.95	0.27
Enjoy cooperation (COOPERATE)	0.04	1.09	0.31	1.01	0.26
Perceived Feedback (PERFEED)	0.32	1.12	0.33	0.92	0.01
Teacher Fairness (UNFAIRTEACHER)	10.22	3.91	9.97	3.82	-0.06
Environmental Awareness (ENVAWARE)	0.58	1.42	0.36	1.15	-0.17
Science self-efficacy (SCIEEFF)	0.35	1.27	0.07	1.14	-0.23
Inquiry-based science teaching (IBTEACH)	0.30	1.13	0.00	0.86	-0.30
Index science activities (SCIEACT)	0.67	1.09	0.19	1.10	-0.44
Sense of Belonging to School (BELONG)	n/a	n/a	-0.22	0.87	
Value cooperation (CPSVALUE)	n/a	n/a	0.29	1.03	
Home educational resources (HEDRES)	n/a	n/a	0.11	1.05	
Instrumental motivation (INSTMOT)	n/a	n/a	0.51	0.82	
Interest in broad science topics (INTEREST)	n/a	n/a	0.27	0.92	
Reading Learning time (RMINS)	n/a	n/a	259.60	136.00	
Mathematics Learning time (MMINS)	n/a	n/a	309.80	151.30	

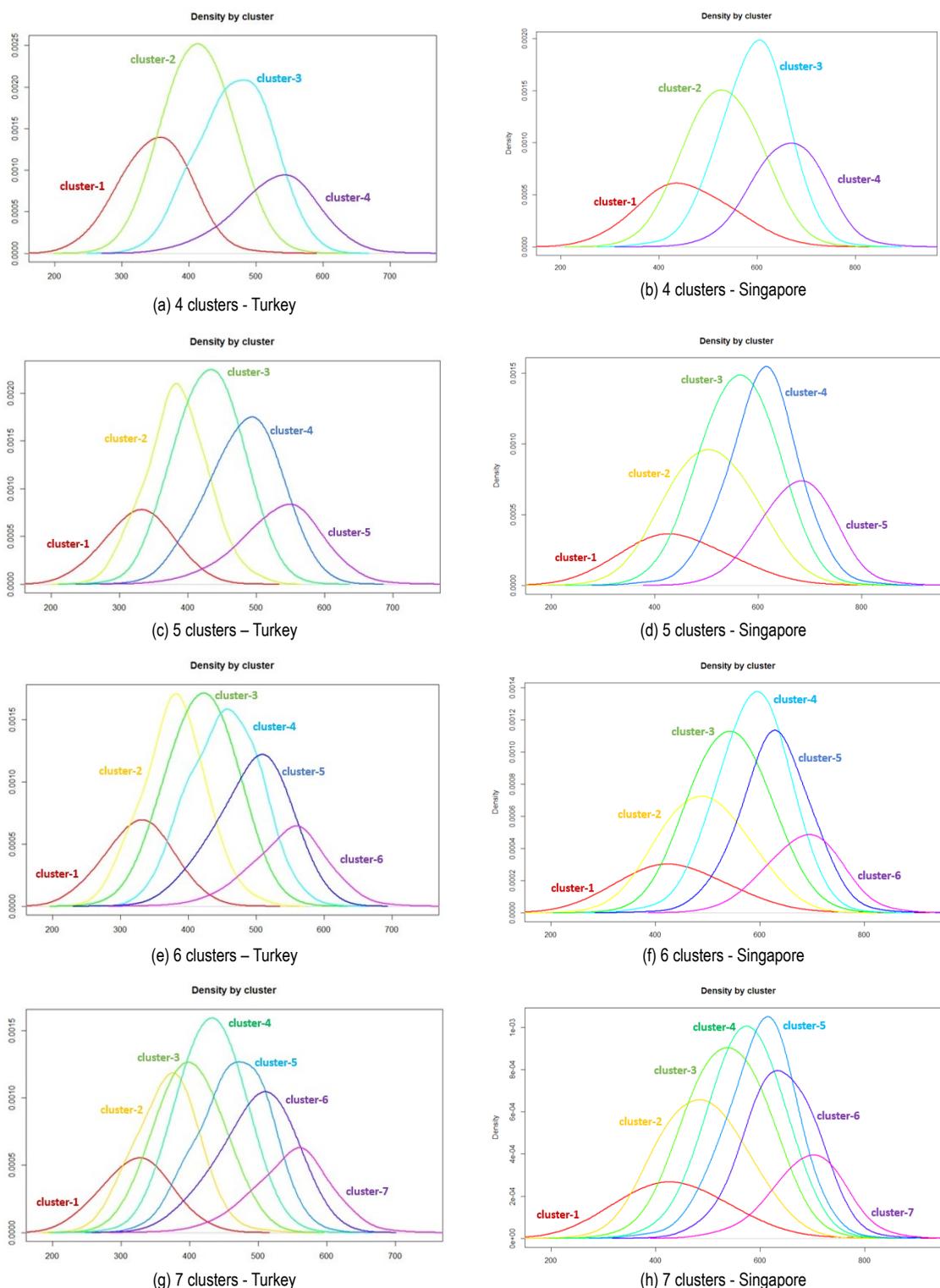
*SD: Standard Deviation*

The standardized mean difference is a measure of the effect size that gives the difference between the two groups adjusted for measurement imprecision and scale (Faraone, 2008). As Table 1 shows, science score, economic, social, and cultural status, home possessions, ICT resources and science learning time in Singapore were too large to be significant than Turkey. Besides, the variables of environmental awareness, inquiry-based science teaching and learning practices, index science activities, science self-efficacy and teacher fairness in Turkey were less efficacious than Singapore (OECD, 2017).

In this research, the QRMIX approach was applied to identify different subgroups based on quantiles where the science achievement of students was statistically differentiated from each other. Graphics of the density functions by clusters (4, 5, 6, and 7 clusters) are shown in Figure 2. Four and five clusters were too simplistic and as a comparison to Table 2, it was decided to continue the 7-cluster model for further analysis.



**Figure 2**  
Density functions of science achievement by clusters



Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used to determine the number of clusters. AIC and BIC statistics are given in Table 2.



**Table 2**  
*AIC and BIC statistics for different clusters*

Models	Turkey		Singapore	
	AIC	BIC	AIC	BIC
4-cluster model	18,364.22	18,386.92	20,243.51	20,266.86
5-cluster model	17,648.63	17,671.32	19,446.03	19,469.38
6-cluster model	17,053.30	17,075.99	18,872.56	18,805.91
7-cluster model	16,553.59	16,576.28	18,057.68	18,249.02

Since the 7-cluster model had the lowest AIC and BIC values, the 7-cluster model was used for further analysis. The number of students, percentages, and R<sup>2</sup> for each cluster are given in Table 3.

**Table 3**  
*The number of students, percentages and R<sup>2</sup> statistics*

Clusters	Turkey			Singapore		
	Number of students	%	R <sup>2</sup>	Number of students	%	R <sup>2</sup>
Cluster-1	303	7%	0.74	343	8	0.88
Cluster-2	579	14	0.94	699	17	0.97
Cluster-3	703	17	0.96	901	22	0.98
Cluster-4	872	21	0.96	887	21	0.98
Cluster-5	733	18	0.97	817	20	0.97
Cluster-6	635	15	0.95	678	16	0.97
Cluster-7	352	8	0.83	303	7	0.85

In order to compare the findings, coefficients, and significance flags of each variable are given in Table 4. In Turkey dataset with the 7-cluster model, there were 303 students in Cluster 1, 579 students in Cluster 2, 703 students in Cluster 3, 872 students in Cluster 4, 733 students in Cluster 5, 635 students in Cluster 6, and 352 students in Cluster 7. In Singapore, these numbers were 343, 699, 901, 887, 817, 678 and 303, respectively.

**Table 4**  
*β coefficients in the QRMIX approach with 7-cluster for Turkey and Singapore datasets*

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5		Cluster 6		Cluster 7	
	TR	SG												
<b>Quantiles</b>	<b>0.04</b>	<b>0.04</b>	<b>0.14</b>	<b>0.14</b>	<b>0.30</b>	<b>0.32</b>	<b>0.48</b>	<b>0.52</b>	<b>0.68</b>	<b>0.70</b>	<b>0.84</b>	<b>0.86</b>	<b>0.96</b>	<b>0.96</b>
<b># of students</b>	<b>303</b>	<b>343</b>	<b>579</b>	<b>699</b>	<b>703</b>	<b>901</b>	<b>872</b>	<b>887</b>	<b>733</b>	<b>817</b>	<b>635</b>	<b>678</b>	<b>352</b>	<b>330</b>
INTERCEPT	331.6*	450.1*	366.7*	513.2*	392.7*	561.9*	415.5*	596.5*	444.4*	628.7*	479.1*	668.3*	522.4*	715.4*
GENDER	0,3	1,5	5.9*	1,7	7.8*	2,1	10.3*	2,4	12.5*	2,5*	13.8*	2,9*	18.7*	2,4*
ESCS	1,1	12.6*	4.1*	12.5*	5.0*	10.8*	5.4*	12.5*	6.9*	12.9*	8.0*	13.2*	15.4*	17.2*
SMINS	0.1*	0.3*	0.1*	0.2*	0.1*	0.2*	0.2*	0.2*	0.2*	0.2*	0.2*	0.2*	0.2*	0.2*
ANXTEST	-7.4*	-9.5*	-5.6*	-7.1*	-5.8*	-3.3*	-5.5*	-4.4*	-5.4*	-5.8*	-6.0*	-6.9*	-5.2*	-5.9*



	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5		Cluster 6		Cluster 7	
	TR	SG												
<b>Quantiles</b>	<b>0.04</b>	<b>0.04</b>	<b>0.14</b>	<b>0.14</b>	<b>0.30</b>	<b>0.32</b>	<b>0.48</b>	<b>0.52</b>	<b>0.68</b>	<b>0.70</b>	<b>0.84</b>	<b>0.86</b>	<b>0.96</b>	<b>0.96</b>
<b># of students</b>	<b>303</b>	<b>343</b>	<b>579</b>	<b>699</b>	<b>703</b>	<b>901</b>	<b>872</b>	<b>887</b>	<b>733</b>	<b>817</b>	<b>635</b>	<b>678</b>	<b>352</b>	<b>330</b>
HOMEPOS	14.6*	4.5*	11.3*	6.6*	7.8*	9.9*	6.7*	11.1*	7.6*	12.0*	7.4*	11.7*	2,9	4,5
ICTRES	-2,5	7.1*	1,5	3.0*	5.3*	0,9	6.1*	-1.2*	6.5*	-0.2	7.2*	1.9*	3,4	3,1
DISCLISCI	3.1*	13.2*	3.4*	9.7*	2.8*	8.7*	2.9*	7.5*	3.3*	7.5*	4.2*	7.9*	4.1*	6.6*
IBTEACH	-3.0*	-8.9*	-4,5	-6.8*	-5.6*	-4.1*	-5.6*	-6.1*	-7.4*	-5.5*	-8.0*	-4.6*	-9.5*	-1,7
TDTEACH	2,1	7.0*	3.6*	5.1*	3.9*	5.2*	3.8*	5.9*	2.9*	5.9*	3.1*	3.7*	3.9*	0,8
ENVAWARE	7.6*	7.9*	8.0*	7.0*	7.3*	5.5*	7.1*	3.8*	6.9*	4.8*	5.1*	2.9*	4.4*	1,8
ENVOPT	-11.8*	-6.6*	-11.3*	-8.1*	-11.3*	-6.7*	-11.7*	-7.5*	-10.8*	-5.9*	-9.0*	-5.7*	-7.5*	-2,1
JOYSCIE	1,1	10.9*	3.8*	13.4*	3.2*	13.6*	3.8*	13.8*	5.7*	14.4*	5.4*	13.7*	6.2*	11.7*
SCIEEFF	0,00	-0,2	1.3*	5.5*	2.0*	6.6*	2.5*	7.6*	3.9*	5.9*	5.0*	9.0*	4.8*	15.0*
EPIST	6.3*	14.6*	6.7*	12.7*	6.9*	11.4*	6.5*	11.1*	6.5*	8.5*	6.9*	8.6*	5.7*	9.1*
SCIEACT	-2.5*	-6.0*	-4.4*	-6.2*	-4.5*	-4.5*	-4.5*	-3.9*	-5.0*	-2.6*	-4.4*	-3.5*	-4.6*	-8.5*
COOPERATE	1,6	6.4*	1.6*	4.5*	1.6*	6.7*	1.8*	5.2*	1.5*	4.5*	2.7*	3.5*	6.1*	3,3
PERFEED	11.6*	12.6*	10.2*	14.7*	8.0*	16.2*	8.7*	16.3	8.8*	14.7*	7.5*	13.2*	9.1*	14.1*
ADINST	7.1*	5.6*	4.4*	8.0*	3.4*	8.3*	3.6*	9.6*	4.5*	8.8*	2.7*	9.7*	3.9*	10.6*
TCHRS	-1.2*	-2.9*	-1.2*	-	-1.1*	-3.3*	-1.0*	-2.8*	-0.9*	-2.6*	-0.9*	-2.8*	-1.1*	-2.2*
BELONG	-	-1,4	-	-4.6*	-	-4.9*	-	-4.5*	-	-6.2*	-	-5.1*	-	-4.3*
CPSVALUE	-	-8.6*	-	-6.6*	-	-9.3*	-	-8.6*	-	-9.0	-	-10.9*	-	-14.5*
HEDRES	-	5.3*	-	1.9*	-	0,3	-	1.2*	-	2.0*	-	0,6	-	2,7
INSTSCIE	-	-7.4*	-	-5.2*	-	-8.4*	-	-8.2*	-	-8.2*	-	-8.6*	-	-7.2*
INTBRSCI	-	2,8	-	1.2*	-	2.2*	-	2.9*	-	3.3*	-	5.0*	-	8.6*
LMINS	-	-0.3*	-	-0,3	-	-0.4*	-	-0.4*	-	-0.3*	-	-0.3*	-	-0.3*
MMINS	-	0.2*	-	0.1*	-	0.1*	-	0.1*	-	0.1*	-	0.1*	-	0,1

$R^2$  statistics were higher than 70%, which is the minimum acceptable level for  $R^2$ , for both countries. In Table 4, students in Cluster 1 had the lowest science achievement score while students in Cluster 7 had the highest science achievement score.

Male students had lower science performance (423) than female students (429) in Turkey while female students had lower science performance (545) than male students (547) in Singapore. Besides, the impact of gender had increased from Cluster 1 to Cluster 7 in both Turkey and Singapore. Index of economic, social and cultural status had a positive effect on students' science achievement in both Turkey and Singapore. In addition, the impact of the independent variable in Singapore was relatively higher than the impact of the independent variable in Turkey. Gender and Index of economic, social and cultural status had a significant effect on science achievement in all clusters, except Cluster 1.

Test anxiety had a negative significant effect on students' science achievement in Turkey and Singapore. Also, the effect of the variable on students' science achievement was almost the same for Turkey and Singapore in all clusters.

Home possessions had no significant effect on students' science achievement in Cluster 7. Furthermore, the impact of home possessions on students' science achievement had decreased from Cluster 1 to Cluster 7 in Turkey. In contrary to the findings in Turkey, the impact of home possessions on students' science achievement had increased from Cluster 1 to Cluster 7 in Singapore. In Turkey, information communication technology had a statistically significant effect on students' science achievement for the students who were in Cluster 3, 4, 5 or 6. Furthermore, its effect had increased from Cluster 3 to Cluster 6. On the other hand, in Singapore, the impact of information



communication technology on students' science achievement was relatively higher for the students who were in Cluster 1 and 2 than others.

The disciplinary climate in science classes, teacher-directed science instructions, environmental awareness, enjoyment of science, science self-efficacy, enjoy cooperation and adaptation of instruction were the factors that affect students' science achievement positively, as expected. However, it was revealed that teacher-directed science instructions, enjoyment of science, science self-efficacy and enjoy cooperation factors had no statistically significant impact on students' science achievement for the students who were in Cluster 1 in Turkey. In Singapore, unlike in Turkey, the impact of disciplinary climate in science classes on students' science achievement is extremely high for the students who are in Cluster 1. Teacher-directed science instructions, environmental awareness and enjoy cooperation factors had no significant effect on students' science achievement for the students who were in Cluster 7 in Singapore.

$\beta$  coefficients were examined in order to determine the variable importance and 10 most important factors for Turkey and Singapore were given in Tables 5 and 6, respectively. The importance of level 1 represents the most important factors affecting students' science achievement.

**Table 5**

*Variable importance of each cluster for Turkey*

Factors	Clusters						
	1	2	3	4	5	6	7
HOMEPOS	1	1	4	5	4	6	-
ENVOPT	2	2	1	1	2	2	5
PERFEED	3	3	2	3	3	5	4
ENVAWARE	4	4	5	4	7	-	-
ANXTEST	5	7	7	9	-	9	9
ADINST	6	9	-	-	-	-	-
EPIST	7	5	6	6	9	8	8
DISCLISCI	8	-	-	-	-	-	-
TDTEACH	9	-	-	-	-	-	-
COOPERATE	10	-	-	-	-	-	7
GENDER	-	6	3	2	1	1	1
IBTEACH	-	8	8	8	5	4	3
SCIEACT	-	10	-	-	-	-	-
ICTRES	-	-	9	7	8	7	-
ESCS	-	-	10	10	6	3	2
JOYSCIE	-	-	-	-	10	10	6
SCIEEFF	-	-	-	-	-	-	10

According to Table 5, it was found that variable importance is differentiated from cluster to cluster. Home possessions, environmental optimism, and gender were the most important factors affecting students' science achievement in Cluster 1 & 2, Cluster 3 & 4 and Cluster 5 to 7, respectively. The second important factor was environmental optimism in Clusters 1, 2, 5 and 6. However, perceived feedback, gender and economic, social and cultural status are the second important factors in Clusters 3, 4 and 7, respectively. In addition, the third important factor was perceived feedback, gender, economic, social and cultural status and inquiry-based science teaching and learning practices in Clusters 1, 2, 4 & 5, Cluster 3, Cluster 6 and Cluster 7, respectively.

Similar to the variable importance findings in Turkey, the level of variable importance in the Singapore dataset was differentiated from cluster to cluster. The most important factors affecting students' science achievement were epistemological beliefs, perceived feedback, enjoyment of science and economic, social and cultural status



in Cluster 1, Cluster 2 to 5, Cluster 6 and Cluster 7, respectively. Furthermore, the disciplinary climate in science classes, enjoyment of science, economic, perceived feedback and science self-efficacy were the factors that were the second important factors affecting students' science achievement in Cluster 1, Cluster 2 to 5, Cluster 6 and Cluster 7, respectively.

**Table 6**

*Variable importance of each cluster for Singapore*

Factors	Clusters						
	1	2	3	4	5	6	7
EPIST	1	3	3	4	7	8	7
DISCLISCI	2	5	7	10	9	10	-
ESCS	3	4	4	3	3	3	1
PERFEED	4	1	1	1	1	2	4
JOYSCIE	5	2	2	2	2	1	5
ANXTEST	6	8	-	-	-	-	-
IBTEACH	7	10	-	-	-	-	-
CPSVALUE	8	-	6	7	5	5	3
ENVAWARE	9	9	-	-	-	-	-
SCIEEFF	-	-	-	9	-	7	2
ADINST	-	7	9	6	6	6	6
INTBRSCI	-	-	-	-	-	-	8
SCIEACT	-	-	-	-	-	-	9
INSTSCIE	10	-	8	8	8	9	10
HOMEPOS	-	-	5	5	4	4	-
ENVOPT	-	6	10	-	-	-	-
BELONG					10		

Based on Table 5 and Table 6, it was revealed that the important factors affecting students' science achievement were quite different between Turkey and Singapore such as home possessions and environmental optimism. This was probably because of the gap between the general economic and cultural levels of these countries and the general education policy of governments.

## Discussion

The data work of this research was composed of Turkey and Singapore datasets, which were obtained from PISA 2015 survey. In this research, students were grouped using their science achievement score and factors affecting their science achievements, simultaneously. Thus, the impact of the science achievement-related factors was compared between Turkey and the top-ranked of the achievement in the PISA 2015 survey, which is Singapore.

In the literature, many researchers have been revealed that gender is an important factor that affects students' achievement (Contini et al., 2017; Ergün, 2019; Gümüş & Chudgar, 2016; Innabi & Dodeen, 2018; Li, Zhang, Liu, & Hao, 2018; Liu & Wilson, 2009; Telteman & Windzio, 2019; Zhou, Zeng, Xu, Chen, & Xiao 2019). However, in this research, gender was not an important factor that affected students' achievement for the students who had the lowest science achievement score in Turkey, which is an important finding that is not supported by other research in the literature. In addition, gender was a significantly important factor for the students' achievement in other subgroups. On the other hand, gender was the most important factor for all subgroups with different impact levels in Singapore. In PISA 2015, male students in Turkey were more successful than female students in terms of science achievement. Similar to the literature, male students were more successful than females in the Eastern Anatolian



Region (Educational Reform Initiative, 2018), which is a chronic problem for Turkey. Although actions that have been taken against gender inequality in the education from Ministry of Education and Non-Profit Organizations, schooling ratios by the secondary school were 65% and 70% for females and males in this region based on Educational Reform Initiative report in 2018. In order to solve this issue, these organizations and the government should keep on running these programs to close the gap between males and females in terms of the rights of education. Besides, the achievement gap between male and female students in terms of science subjects in Singapore is not statistically significant.

In the PISA study, the index of home possessions was calculated using Item-Response Theory (IRT) with 20 different items. In Kılıç Depren's research (2018), the average home possessions score should be higher than -0.2221 for better science performance. However, it was -1.39 for Turkey, which is very low when other countries that participated in the PISA survey are taken into consideration. In this research, home possession was the most important factor for students who were in Cluster 1 and 2. In these clusters,  $\beta$  coefficients of home possession were 14.6 and 11.3, respectively. Furthermore, it had a statistically significant impact on students' science achievement for students who were in Clusters 3, 4, 5 and 6. These findings are consistent with the literature in the possession at home (Singh, Granville, & Dika 2010; Yang, 2010). On the other hand, home possession had no statistically significant effect on the achievement of students who were in Cluster 7. Students who were in Cluster 7 had almost all of the home possession-related items such as a desk to study at, a room of their own, a quiet place to study, etc. Thus, it is not an improvement area for these students in Turkey. Educational policymakers, families, and non-profit organizations should provide some of the items such as a computer, educational software and a link to the internet in school as a short-time solution, especially for the students who have the lowest performance score in science achievement. In this research, the average home possessions score was -0.17 in Singapore, which was higher than the average score of the home possessions score of Turkey. Additionally, the possession at home has the potential to increase in achievement (Chen, Elchert, & Asikin-Garmager, 2018; Pokropek, Borgonovi, & McCormick, 2017).

The economic, social and cultural status of a student was another important effect on students' achievement, which has been frequently emphasized in the literature (Marks, Cresswell, & Ainley, 2006; Turmo, 2004; Zwick, Ye, & Isham, 2019;). In the study of Oliver, McConney, and Woods-McConney, it was revealed that student ESCS and science achievement score were highly correlated in a positive way (Oliver, McConney, & Woods-McConney, 2019). To be increased students' science achievement, it had a significant factor, especially for students of Cluster 7 in Turkey. However, it did not have a significant effect on students' science achievement for students who had the lowest performance. The economic, social and cultural gap between people in Turkey has been the most important issue for a long time. GDP per capita (current \$) was 9,3113\$ in Turkey in 2018. In Singapore, which is the top performer country in PISA 2015, it was 64,582\$ (World Bank, 2019). It is obvious that the Turkish government should create action plans to increase the health and decency standard of living. In contrast to Turkey's status, Singapore has a larger share of education's contribution to the GDP (Sanders, 2019). In addition to this, a strong link between science achievement and socioeconomic status in Singapore had been predicted.

Environmental optimism criteria consist of having sufficient knowledge about environmental issues. The average score of this factor for Turkish students was -0.61, which shows that Turkish students do not have sufficient knowledge about it and also, they are not optimistic about the future expectation of these criteria. In the literature, this score should be higher than 2.2486 to increase science achievement for Turkish students (Kılıç Depren, 2018). Specifically, there is evidence that environmental optimism positively influenced students' science achievement (Hoy, Tarter, & Hoy, 2006; Littledyke, 2008; Mutlu & Nacaroğlu, 2019). This analysis demonstrated significant differences at parameter estimations from cluster to cluster. According to the literature, the impact of environmental optimism on Turkish students' science achievement has been much more important than other countries that have been tended to perform better than Turkey. The main reason for this is that the actions related to environmental awareness were started to apply in the early 1980s by the Turkish government, but the major policy was able to be included in the 10th development plan in 2014 (Smith, 2015).

On the other hand, it is expected that environmental awareness and optimization scores were going to increase in the near future after the actions taken from the Turkish government in 2014. Contrary to the actions taken by the Turkish government, environmental awareness and protection policy has been started in the early 1970s in Singapore (Hay, 2008). With this action, Minister's Offices were established to carry out action plans about different environmental problems such as water pollution and protecting animals. As a result of the action plans that were applied by the Singapore government, it can be said that the average awareness score of the environmental issues of Singaporean students is relatively higher than Turkey.



Perceived feedback score was calculated using IRT with 5 different items. In both Turkey and Singapore, perceived feedback was a common important factor affecting students' science achievement. The average scores of perceived feedbacks were 0.32 and 0.33 in Turkey and Singapore, respectively. This was one of the strongest areas of Turkey based on the referenced country.

The information communication technology score was calculated using IRT with 6 different items. Information communication technology was not a significantly important factor in students' achievement for students who were in Cluster 1, 2 and 7 while it was an important factor for students who were in Clusters 3, 4, 5 and 6. According to Gallup's survey conducted on November 11th to December 25th in 2013 to reveal media usage routine in Turkey (Gallup, 2013), 72% of participants in Turkey had a computer, 68% and 72% of participants had an internet connection and a cell phone, respectively. These findings show that the familiarity of information communication technology should be improved in Turkey because it was a statistically significant factor to increase students' achievement for students who were in Clusters 3, 4, 5 and 6, which was 70% of the population in this research.

The finding appears that learning time had a significant effect on students' science achievement (Chandler & Swartzentruber, 2011; Kiliç Depren, 2018; Sha, Schunn, & Bathgate, 2015;). The average science learning time was around 207 minutes per week for Turkish students and 324 minutes for Singaporean students according to the PISA 2015. In this study, science learning time was one of the statistically significant factors influencing students' science achievement for all students. As pointed out by Kiliç Depren (2018), the minimum level of science learning time should be 333 minutes per week in order to reach a better level of success. It is obvious that the Turkish government should consider the current learning times of the subjects.

Teacher-directed science instruction, science self-efficacy, enjoyment of science and enjoy cooperation were the important factors for students' science achievement in Turkey, except the students who were in Cluster 1. These findings were in the same direction as previous studies (Henno & Reiska, 2013; Özdem, Çavaş, Çavaş, Çakıroğlu, & Ertepinar, 2010;).

## Conclusions and Implications

As highlighted in the introduction, measuring, monitoring and improving the science achievement of a student is crucial for policymakers to understand what students can do with the knowledge they have learned and how they can adapt their knowledge in their real-life, which is the main purpose influencing achievement in PISA survey. If science achievement is provided as evidence of educational attainment, Turkey and Singapore have very different achievement levels in science. Because of this, it is needed to understand how to improve science achievement in Turkey that is relatively below the OECD average in PISA 2015. To compare the results, Singapore is taken into consideration.

As a result of this study, it is stated that students who have the lowest science performance should be supported with home possessions, perceived feedback, environmental awareness, and optimism in Turkey. In Singapore, students who have the lowest science performance should be supported with perceived feedback, enjoyment of science and epistemological beliefs. Since the sub-criteria of home possessions are taken into consideration, it is not possible to increase the level of home possessions in a short time period. There is more need for family assistance in some of the sub-criteria such as a desk to study at and a quiet place to study, which may be particularly provided by parents. In addition to this, in schools, working groups that are led by the teacher should be created for the whole-class discussions about science subjects. Thus, the level of students' interest and enjoyment of science and cooperation perception about studying can be increased.

The results of the study show that economic, social and cultural status and information communication technology are the factors affecting students' science achievement. Therefore, the efforts that have been captured by the Turkish government, such as computer laboratory with internet access and school materials, should be continued.

In addition, environmental awareness and environmental optimism have significant effects on students' science achievement. The government should provide in-service training to teachers and education policymakers to promote environmental knowledge.

In conclusion, students were divided into 7 clusters according to their level of science achievement using QRMI, which is consistent with the PISA 2015 scientific achievement scale. With this proposed method, it was revealed that different factors had a different impact on science achievement for each cluster. Thus, an action plan for all students cannot be created. Different action plans should be taken for students who have different achieve-



ment levels. In this study, the most crucial determinants in science achievement levels were discussed and action plans that should be taken were given.

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